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INTERPLANETARY ORBITS

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(*A paper read to the British Interplanetary Society in London on January 5, 1952.*)

This talk is concerned only with the fundamentals of orbit-work, and mainly with those of the Earth-Moon system; and I want, in particular, to deal with some of the common fallacies that are all too prevalent in discussions of this subject. There is, for example, a sort of implicit faith in the accuracy of astronomical data which is out of all proportion to the truth. The astronomer works with seven-figure tables, therefore his work must be very accurate. That seems to be the common idea—yet the seven-figure work merely represents the accuracy which the observer hopes to reach in his measurement of angles, i.e., an accuracy of 0″·1. This angle, at the distance of the Sun from the Earth, implies a possible error of nearly fifty miles, which would, perhaps, be acceptable to the navigator of a space-ship. But it is very doubtful if the co-ordinates of the Sun and planets are known to an accuracy of more than five decimal places (in astronomical units), so that the errors in position are certainly to be measured in thousands of miles.

The interesting point arises that an error of 0·00001 units may always be treated as an infinitesimal, because its square may be neglected when we work in units of the seventh decimal. And so the differential calculus is used to deal with our subject, and its formulae spread like some malignant disease over the pages of your *Journal*, giving an entirely false impression of omniscience. These formulae may give an overall picture of space-flight, but the picture is a large-scale one; the navigator of a space-ship will not be inclined to regard a thousand miles as an infinitesimal! And let it be admitted quite frankly that the astronomer is becoming increasingly aware of the inadequacy of the old classical mechanics to represent the motion of the members of the solar system.

There is always a difficulty in accepting these new ideas—you have probably felt it yourself! The problem of space-flight is an astronomical one, in which the space-ship may be regarded as falling freely under gravity. Its path is a curved one—for there are no straight lines in space—a curved path (or orbit) about the sun or one of the planets. You were probably taught at school that the path of a projectile is a parabola. This is perfectly true if gravity is constant at all points—a condition which would only arise on a flat earth. Curve the earth, and, the parabola becomes an ellipse. All of the projectiles which we have so far managed to get off the earth's surface have travelled in

ellipses, with the centre of the earth at one focus; and in order to travel in a parabolic orbit, the projectile must have a much greater velocity than we have yet managed to give to it. At a distance r from the centre of attraction, the velocity of a body travelling in a conic of semi-major axis a is given by

$$V^2 = k^2 m\left(\frac{2}{r} - \frac{1}{a}\right) \quad .. \quad .. \quad .. \quad (1)$$

where k is a constant related to the universal constant of gravitation, and m is the mass of the attracting body. The orbit may be any one of the conic sections; for in an ellipse, a is a positive quantity, but it becomes infinite in the parabola, and negative in a hyperbola. In these last two cases, the body will recede from the centre of attraction, never to return. Clearly then, we can travel from the Earth to the Moon, or to one of the planets, in any one of these types of orbit, but since we shall start at perigee, that point in the orbit which is nearest the Earth's centre, our destination will always lie at a far distant point. This implies that if we choose to travel in an elliptical orbit, the value of a will be very large, since our destination will lie at the other end of the major axis. It is then clear that we must leave the Earth with a velocity which approaches that for parabolic motion. The difference between the two velocities at the starting point is always small, but it becomes very much greater as we recede from the earth. The effect of changing this initial velocity is shown in the following table, from which it will be seen that only a very small change of initial speed is necessary to change the orbit from an elliptical one which reaches the Moon (at 384,000 km.) to a parabola.

V	39·7	39·8	39·9	40·0	40·1	40·2	40·3	$\times 10^3$ km./hr.
a	125	154	204	294	526	5,000	∞	$\times 10^3$ km.

The journey from the Earth to the Moon is often dismissed as being the easiest to think about. The Earth and the Moon, we are told, are close together (astronomically speaking) and since the sun is nearly 400 times as far away, we can ignore it, because it has the same effect on both of these bodies. This simplifies matters, because we can now deal with just the Earth and the Moon. Unfortunately, as we shall see, it simplifies matters too much! However, let us proceed blithely with our fallacious ideas and see where they lead us. The simplest plan for this trip would seem to be to travel in an elliptical path, just big enough to reach the orbit of the Moon, timing our start so that at the other end of the ellipse, the Moon will come along at just the right time, and overtake the space ship. It should be noted that the Moon will overtake the ship, because its orbit is larger. Reference to equation (1) will show that at a given distance r, the velocity will be greater for the larger values of a.

We set off, then, in an easterly direction, with a speed of 40,000 km./hr., but this rapidly diminishes, until, at the other end of the major axis it is only 630 km./hr. Table I gives the times and speeds at various parts of the path, together with the corresponding figures for the parabolic orbit. The longitudes in the orbit are measured from 0° at the start to 180° at the other end of the major axis. It will be noticed how rapidly the first part of the journey is completed.

TABLE I

Longitude	Ellipse			Parabola		
	r	Time (hrs.)	V	r	Time (hrs.)	V
°						
0	6·4	0·0	40	6·4	0·0	40
90	12·6	0·4	28	12·8	0·4	28
120	24·4	1·0	20	25·6	1·1	20
130	33·4	1·6	17	36·0	1·7	17
140	48·6	2·6	14	55	3·1	14
150	77·6	5·2	10	96	6·7	10
160	139	12·6	7·0	212	21·1	7·0
170	270	51·8	3·5	394	—	5·1
180	384	119	0·63	—	—	—

The units of r and V are 1,000 km. and 1,000 km./hr. respectively.

Now it is a simple matter to calculate the velocity of the Moon in its orbit, and we find that it has a mean value of 3,700 km./hr. We can now consider the question of making a safe landing on the Moon. If the relative speed of the ship and the Moon could be obtained from the figures given above, the problem would be easy. In the elliptical orbit the ship will be travelling at 630 km./hr., and the Moon will be overtaking it, travelling in the same direction, at 3,700 km./hr. The relative speeds would then appear to be 3,100 km./hr., and since the Moon has no atmosphere sufficient to provide a brake on the speed, the jets would have to be used to retard the ship. Compare this with the parabolic motion. Here the ship will still be travelling at nearly 6,000 km./hr. when it reaches the Moon's orbit, which it will approach almost at right angles. The relative speed in this case will be of the order of 7,000 km./hr., and if these figures were the whole story, it would appear quite obvious that the elliptical path is far more economical of fuel both at the beginning and at the end of the journey.

These high speeds of approach to the Moon have given rise to yet another fallacy, that it would be far more economical and efficient to send the ship to the neutral point between the Earth and the Moon, from which position it could fall with a relatively low speed on to the Moon's surface. The fallacy here is simply that the Sun has been neglected. Without it, there is, of course, a neutral point between Moon and Earth where the gravitational attractions exactly balance. But at this point (approximately 38,000 km. from the Moon) the attraction of the Sun is almost double that of either Earth or Moon. The Sun is always the dominating power in our part of the solar system, and the neutral point is merely a fiction—a space ship which reached this point with negligible speed, would come under the influence of the Sun, describing an orbit about it ever afterwards. We are so accustomed to regarding the Moon as a satellite of the Earth, that we forget that it is really a planetary body, its orbit being always concave to the Sun, which really controls it.

So let us forget the neutral point, and return to the plain case of an orbit to the Moon. So far we have ignored the attraction of the Moon itself, yet

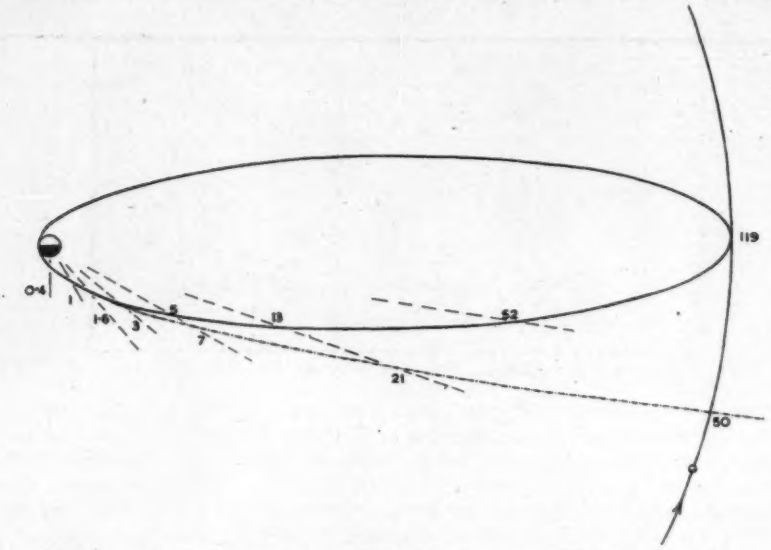

FIG. 1. The Earth-Moon orbits, showing the time in hours in both elliptical and parabolic orbits.

this may well be a serious matter. If, at a given distance from the Moon, the space ship is travelling with a speed which is greater than the parabolic speed (referred to the Moon as centre) at that distance, then the effect of the Moon's attraction will be to change the orbit into a hyperbola about the Moon's centre. This is the common effect of the Earth on meteors, and the mathematical methods which are used in that case can be applied to a study of motion about the Moon. Given the ship's speed, we can calculate the maximum distance of the original orbit from the Moon in order that the ship may make a grazing landing on the Moon's surface. The results are shown in Table II, in which V_1 is the speed in the original Earth-Moon orbit; V_2 is the speed of landing, relative to the Moon, and a and b are the semi-axes of the hyperbola. The quantity b actually gives the distance from the centre of the Moon (radius 1,740 km.) to the original orbit.

TABLE II

V_1	V_2	a	b
0·6	8·5	101	14·3
1·0	8·6	36·4	8·6
2	8·8	9·1	4·4
3	9·0	4·0	3·0
4	9·4	2·3	2·4
5	9·9	1·4	1·98
6	10·4	1·0	1·74

The unit of V_1 and V_2 is 1,000 km./hr.; a and b are in terms of the Moon's radius.

It is now seen that even in the case of an elliptical orbit, the speed of approach to the Moon will be very high, and a considerable expenditure of fuel will be necessary to provide braking. The elliptical orbit presents

no advantages, after all, and it will clearly be just as efficient to travel in a parabolic orbit, taking about 50 hours, instead of the elliptical one, taking nearly five days.

This behaviour in the neighbourhood of an attracting body is one of the simplest cases of perturbations in an orbit, but the more general case is far more complicated, since it involves a consideration of the complicated motions of the planets. In computing practice it is usual to resolve the perturbative forces into three components along axes at right angles. It is then not difficult to investigate the effect of these components on the orbit; but as far as a space ship is concerned, most of these are of little importance, since only a part of the orbit will normally be completed. There is one outstanding point, however, in the effect of an increase of speed on the size of the orbit. Consider, for example, the effect of a forward force acting tangentially to the orbit, caused either by the attraction of a planet, or by the action of the jets. The effect will be to increase the speed, and from formula (1) it is seen that such an increase at distance r can only be obtained by an increase in a. Hence a force of this kind will always increase the size of the orbit, the curvature of the path diminishing. May I repeat that there are no straight lines in space?

The actual case is, as I have said, much more complicated, since the attraction may take place at any angle, and it is never constant, since it varies in accordance with the law of gravitation. Since the forces acting on the ship are always varying, the resulting changes in velocity and position are to be obtained by a process of integration of the equations of motion, or rather of the computed values of these expressions. The principle of such a method is easily shown by considering the behaviour of a falling body in a constant gravitational field. For simplicity, assume that the acceleration due to gravity is 1,000 cm./sec.^{2} Then a freely falling body will acquire a velocity of 500 cm./sec. after half a second, and by adding increments of 1,000, we obtain the velocities at the middle of all subsequent intervals of one second. Since the initial speed is zero, the body will have covered 500 cms, by the end of the first second, and the total distance travelled is always to be found by adding on the successive values of the velocity at the mid-interval. The scheme is shown in the left-hand part of the table that follows, and it will be seen that the distances, obtained in this way by simple addition (for that is all that is implied in integration), agree exactly with the formula $s = \frac{1}{2} a t^2$, while the velocities are those given by $v = a t$.

Now consider the effect of a small increase in the acceleration, as shown in the second, third and fourth intervals in the right-hand part of Table III. The velocity increases, but after the change of acceleration has died out, its effect remains. The velocity is larger than it was in the first part of the table, and the effect on the distances continues to accumulate. After a considerable interval, the change in the distance will be very large indeed. The importance of this effect cannot be over-estimated. A small perturbation does not have a small effect—the effect remains, and it goes on accumulating. For this reason it is essential that the initial conditions of velocity, distance, and angle of projection of the space ship must be very accurately specified, and any corrections that are to be made to the orbit should be made at the earliest

TABLE III

t	s	v	a	s	v	a
0	0		1,000	0		1,000
		500			500	
1	500		1,000	500		1,000
		1,500			1,500	
2	2,000		1,000	2,000		1,001
		2,500			2,501	
3	4,500		1,000	4,501		1,002
		3,500			3,503	
4	8,000		1,000	8,004		1,001
		4,500			4,504	
5	12,500		1,000	12,508		1,000
		5,500			5,504	
6	18,000		1,000	18,012		1,000
		6,500			6,504	
7	24,500		1,000	24,516		1,000

possible moment. As Herrick has pointed out,[1] it is the initial impulse that is important.

The standard methods used in astronomy for predicting the effect of perturbations proceed on similar lines, the three components of the attractions being integrated separately. With modern high-speed electronic machines, the method can give results very rapidly, and some such method will be necessary to provide the navigator with a great variety of pre-computed orbits which will equip him for any emergency. There certainly would not be time, when the emergency arises, to carry out such a calculation on board. The simple ideas which I have put forward have taken no cognisance of such things as the inclinations of the orbits, the effect of errors in the starting time and speed, and the presence of other planets, all of which will have some effect on the path. And when it is considered that none of these things will be of the slightest value until the outstanding problem of a method of navigation is solved—then you will agree with me that there yet remains a great deal to be done.

REFERENCE

(1) S. Herrick, "Space Rocket Trajectories," *J.B.I.S.*, **9** (5), p. 235, September, 1950.

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ROCKET FUELS DEMONSTRATION

(*A report of the Lecture-Demonstration by Dr. W. R. Maxwell to the British Interplanetary Society in London on March* 1, 1952.)

Introduction

Dr. Maxwell commenced by pointing out that whereas other engines derived energy by burning fuel in the atmospheric oxygen, the rocket *carried* both its fuel and oxygen supply with it, and was therefore independent of the surrounding air.

Rockets could be classified into two types:—

(*a*) *Bi-propellant*, where the fuel and oxygen supplies are carried in separate tanks and injected separately into the combustion chamber.

(*b*) *Mono-propellants*, where the fuel and oxygen are combined in a single substance. All solid propellant rockets belonged to this class, but liquid mono-propellant types also existed.

Liquid Propellants

(1) BI-PROPELLANTS.

After his opening remarks, Dr. Maxwell then considered the various liquid bi-propellant systems, and stated that it was customary to classify these under the oxidant, as most of the problems arose when dealing with this.

(*a*) *Liquid oxygen.*—The obvious theoretical starting point (and historically the first to be used) was oxygen itself in liquid form. (At this point Dr. Maxwell demonstrated the properties of liquid oxygen, a pale blue liquid which boiled constantly on being exposed to the room temperature.)

Rubber immersed in the liquid oxygen became so brittle that it was crumbled by a hammer, while a bar of lead, on attaining the temperature of the liquid oxygen (−183° C.), emitted a ringing note on being struck.

It was pointed out that these facts were no mere curiosities, but held very real problems for the engineer. It was difficult to find materials which remained soft at liquid oxygen temperatures which could serve as seals, valve seats, etc., and the physical properties of metals changed much at these temperatures. For example, softer metals such as copper and aluminium gained in strength and became more suitable for many purposes than the steels, which became brittle.

The chemical properties of liquid oxygen were those of the gaseous oxygen which it produced. It was shown, for example, that oxygen rekindles a glowing splint, and iron burned fiercely in it—a point to note in the construction of combustion chambers! It was also shown how textile materials soaked up the liquid oxygen and held both it and the gas for some time, thus constituting a serious fire hazard. A piece of cotton wool so treated disappeared in a flash on the application of a match, and this was followed by the instant immolation of a cigarette (not one of Dr. Maxwell's).

(*b*) *Hydrogen peroxide.*—The second oxidant considered was concentrated

hydrogen peroxide (80 per cent. H_2O_2), commonly termed H.T.P. and well known as the oxidant of the Me 163 Walter motor.

H.T.P. is rather an unstable substance, its decomposition being catalyzed by many substances, and the choice of materials for containers, etc., leads to many problems.

It is stabilized by the addition of small amounts of such substances as phosphoric acid, or 8-hydroxyquinoline, and physiologically, is not very dangerous, as Dr. Maxwell demonstrated by pouring some on his hand! If left on the skin, it causes "burns" of a transient nature, but the rapid application of water can obviate any effects, even upon the eyes.

Its instability also leads to its use as a mono-propellant, in which case the problem is the reverse of stabilization, i.e., positive catalysts to ensure rapid decomposition being sought. The various permanganates, chromates, and dichromates are among the substances which can be used for this purpose, and the effectiveness of such decomposition was demonstrated by directing a stream of peroxide on to some "catalyst stones" (permanganate impregnated) in a beaker, which resulted in instant conversion into a cloud of hot steam and oxygen.

Besides its direct use in the so-called "cold" rocket motor (e.g., the D.H. "Sprite"), the decomposition of peroxide is of great importance for auxiliary equipment, e.g., the turbo-pump of the V.2 was driven by peroxide steam.

The steadiness of reaction for this purpose was shown by Dr. Maxwell in directing a stream of peroxide from a pipette into a stream of permanganate solution issuing from a burette. The two streams met in mid-air with a hissing sound and the continuous production of steam.

However, the decomposition reaction does not make full use of the chemical energy inherent in the H_2O_2 molecule, and H.T.P. is used as a true oxidant in bi-propellant systems.

Its oxidizing powers were demonstrated by dropping some on to a piece of dirty rag, which burst into flames. This indicated that hydrogen peroxide is capable of initiating spontaneous combustion, and a propellant system using this property is termed "self-igniting." The standard partner for H.T.P. in this connection is "C-fuel" (57 per cent. methanol, 30 per cent. hydrazine hydrate, 13 per cent. water and 0·3 per cent. of potassium cuprocyanide as a catalyst).

At this point the high-light of the demonstration was reached, viz., the twin-jet apparatus. The H.T.P. and the C-fuel were held in two cylindrical glass tanks, and were forced by nitrogen from a pressure cylinder through two glass nozzles in two fine jets, which were trained to intersect a few inches away from the nozzles. The two liquids united and proceeded as one stream, almost instantly bursting into flame. However, it was not quite instantaneous, and the measurement of this "ignition delay" between mixing and ignition is of great importance, for if there is any undue delay in ignition, a large amount of propellants will collect in the combustion chamber, and ignition will be accompanied by an explosion which may destroy the motor, as occasionally happens.

The determination of the ignition delay is carried out by observing the position of the points of contact and ignition, and measuring their ordinates by

means of a cathetometer. The time between contact and ignition can be calculated because the vertical component of the trajectory is due to free fall under gravity.

The twin-jet apparatus is also used for studying changes in the flame brought about by varying the oxidant/fuel ratio, changes of catalyst, etc.

As a suitable anti-climax, Dr. Maxwell next made the point that peroxide could also be used in non-hypergolic combinations, e.g., with paraffin, and proceeded to pour the peroxide on to some paraffin in a test tube. Nothing happened; for this reason such propellants need an ignitor (spark plug, pyrotechnic, etc.) in the combustion chamber.

(*c*) *Nitric acid.*—Dr. Maxwell then dealt briefly with the last of the three standard liquid oxidants at present in use, i.e., nitric acid. As used in rocketry, this is 98 per cent. strength HNO_3, and termed white fuming nitric acid, or W.F.N.A. The physiological actions of nitric acid are well known and serious. Although corrosion and sealing problems are more difficult than for its rivals, nitric acid has a high density, is far cheaper than peroxide, and has none of the low-temperature problems of liquid oxygen.

It is capable of entering into self-igniting combinations, as was shown when a little nitric acid was dropped from a pipette into some furfuryl alcohol ($C_4H_3O.CH_2OH$) in a watch glass and burst into flames.

(2) MONO-PROPELLANTS.

(*d*) *Methyl nitrate.*—Dr. Maxwell then turned to liquid mono-propellants, and chose methyl nitrate as a representative in the form known as "Myrol," 60 per cent. CH_3NO_3, 40 per cent. CH_3OH.

A characteristic of Myrol is that when ignited it burns in two distinct stages. The primary combustion results in an invisible but hot flame, while the end products of this reaction are themselves inflammable and burn in air with a luminous flame.

Dr. Maxwell proceeded to demonstrate this by means of a narrow-necked metal container partially filled with Myrol. The vapours were ignited at the neck and burned with a yellow flame, which was then blown out. Nothing appeared to be happening but the lecturer affirmed that the container was getting hot. Soon, however, the afternoon audience had ample evidence that something *was* happening, for one of the products of the primary combustion was formaldehyde! (The experiment was modified for the evening audience and was performed in a glass container behind a thick perspex shield.)

The secondary combustion was allowed to continue at the neck, and the primary reaction was rendered visible by the ebullition at the surface of the liquid.

Solid Propellants

These are by far the older and more familiar propellants, as represented by the ordinary firework.

The solid rocket has a great advantage over the liquid in simplicity of construction, for it is, in effect, merely a combustion chamber filled with propellant. It suffers from lack of control, i.e. its inability to be stopped and re-started, as well as from the fact that by its very nature it has to be regarded as an explosive,

with all the attendant hazards. In addition, it has on the whole, a lower theoretical specific impulse.

(*a*) *Gunpowder.*—The oldest of the solid propellants and certainly the most familiar is gunpowder. Dr. Maxwell showed some of its physical properties by applying a fuse to a small amount of black powder grains in a dish—the result being a flash and a puff of smoke. Some powder which had been pressed down hard in a strong steel tube, on ignition, burnt with a roaring intense flame, appearing indeed, more like a rocket motor than anything else in the demonstration!

(*b*) *Cordite.*—In cordite, Dr. Maxwell presented an example of the modern solid rocket propellant (the "Z" anti-aircraft rockets of the last war were cordite rockets).

Like Myrol, cordite exhibits the phenomenon of secondary combustion. Dr. Maxwell lit a stick of cordite which burnt with a luminous flame which crept quickly down the sides and converted the end into a conical "pencil" shape. A second stick was then ignited, and the secondary flames blown out. A small flat primary flame was then seen to be burning at the end of the cordite, the stick retaining its cylindrical shape. This served to introduce the fact that the actual burning surface is one of the chief considerations of the solid rocket designer.

This concluded a very interesting and instructive lecture, and many members afterwards availed themselves of the opportunity to examine the twin-jet apparatus and various substances demonstrated.

Dr. Maxwell is Superintendent of Research at RAE/RPD, Westcott, and the lecture was given by permission of the Chief Scientist, M.O.S. Especial thanks are due to Dr. Maxwell for kindly consenting to give lectures in both the afternoon and evening, in an effort to accommodate all the members who wished to attend.

Acknowledgement is also due to the authorities of the Regent Street Polytechnic, London, W.1, for the use of the Chemistry Lecture Theatre, and for other assistance.

SOLAR SYSTEM NOTES—4

By Patrick A. Moore, F.R.A.S.

During the first few months of 1952, Mars dominated the evening sky. Opposition occurred on May 1, and the planet can still be seen low down in the west just before sunset. The opposition was not a close one; however, some interesting observations were made in Great Britain, America, Germany and Japan, and a brief review of them may be useful.

The northern polar cap was tilted towards the Earth, and seems to have behaved perfectly normally. As it melted the usual dark fringe, once thought to be a temporary "polar sea" but now considered to be largely an atmospheric phenomenon, was clear; on October 21, 1951, Saheki in Japan saw two dark "knots" in it. Later on it faded, and, by opposition, was very difficult to make out at all. Now and then detached portions of the melting cap were seen; Baum, in England, recorded several. The southern polar snows could be made out, but displayed no unusual features.

Many "canals" were recorded, but, as usual, the observations were discordant. Some observers drew them sharp and linear, others, broad and diffuse. It must be admitted that only very large telescopes are capable of giving reliable results, and canal-covered drawings made with small instruments must be treated with the greatest reserve.

The chief feature of the past opposition was the large number of clouds recorded. As is well known, these clouds cannot be regarded as analogous to our own; the "blue" clouds are probably made up of lofty, fine ice-crystals, while the "yellow" clouds may well be dust-storms. More than twenty were seen in 1951–2; most of these were of short duration, but one or two are worthy of special mention.

On October 30, 1951, the Japanese observers recorded a particularly conspicuous cloud, and followed it until November 8. It moved steadily across the Martian surface at an estimated speed of 13 m.p.h. until it finally vanished. A second cloud, also discovered in November by the Japanese workers, moved even more rapidly (20 m.p.h.) and persisted for several days. A large cloud was followed from March 27 to April 10, 1952, by Sandner and Kutscher, in Germany; and an intensely bright cloud over the desert region known as Aeria was seen in April by several British observers, including the present writer. There are plenty of other examples, and altogether there seems to have been considerable atmospheric activity.

At 21 hours on December 8, 1951, Saheki in Japan noticed a small, starlike spot over the area known as Tithonius Lacus, not far from the south pole of Mars. During the next few minutes it decreased in brilliancy and became larger, finally fading out in less than half an hour. It is most unfortunate that no other observations of it seem to have been made. Saheki has suggested that it was due either to an impact-flash caused by the fall of a large meteorite, or by the eruption of a volcano. There are grave difficulties in the way of both these theories, but at all events it was a most interesting phenomenon.

Our knowledge of the weather conditions on Mars is still very imperfect, and observations of clouds are most important. However, it does seem safe to say that the first weather forecasters stationed on the Red Planet will have an easier task than their opposite numbers on the Earth!

Unusual cloud seen on Mars by T. Saheki, 16th January, 1950.

None of the great observatories appear to have paid special attention to Mars during the past opposition. However, the planet will be better placed in 1954, and in 1956 will be at its closest. Extensive programmes are being planned by the French observers at Meudon and the Pic du Midi, and also at Mount Wilson and Mount Palomar; it may thus be possible to decide, once and for all, whether the celebrated canals are true linear features, or whether they are simply made up of disconnected spots and streaks.

THE DETERMINATION OF MINIMAL ORBITS

By Derek F. Lawden, M.A.

ABSTRACT

The solution to the problem of the transfer of a rocket between two coplanar orbits about a centre of attraction using a minimum of fuel is stated and is applied in the particular case of transfer between two similar elliptical orbits differing only as regards the orientations of their axes.

1. Introduction

Although several authors[1,2,3] have recently pointed out that a true interplanetary space ship, as distinct from a rocket employed for ferrying stores and personnel from a planet's surface to a terminal orbit about the planet, is likely to be powered by a low thrust motor, so that trajectories of least fuel, which inevitably involve impulsive drives at a number of points connected by arcs of free orbit, cannot even be approximated to, it is still a fundamental navigational problem to determine these optimum trajectories in order that they may be employed as a criterion with respect to which the excellence or otherwise of any practical trajectory may be judged. Again, the science of interplanetary navigation can scarcely be described as in a satisfactory state until equations are available for the determination of such an optimum orbit under very general specified conditions, and although experience derived from numerical computation of a large number of interplanetary journeys via arbitrarily selected orbits may be useful as an alternative in the absence of such a general solution of the problem, as a foundation for a new science it cannot be described as firm! A very general mathematical statement of this basic problem has been given by the author in this *Journal*,[4] together with a solution in the case of a uniform gravitational field. A solution for the general case has not been forthcoming and perhaps is not to be expected at this stage. After a uniform field, the case of the inverse square law field presents itself as the next problem to be attacked and it is the purpose of this paper to present a partial solution of this problem, together with a number of computations of particular cases. The solution which we have derived is that of the problem of optimum transfer of a rocket between two coplanar elliptical orbits described in the same sense about the same centre of inverse square law attraction. Minimization of fuel expenditure has been achieved with respect to the trajectory of transfer and the time of transfer together, i.e., the latter quantity cannot be supposed initially specified, but is chosen by the solution equations to take such a value that the fuel expenditure is minimised. As has been pointed out[3], we may look forward to a time when conservation of fuel will not appear to be so urgent as it is at present and then we may choose to sacrifice fuel economy to the need for taking other times of transfer than those corresponding to minimum fuel expenditure. Under such circumstances, the solution proposed below is no longer applicable, but it may be expected that in the early stages of development the necessity to economize in fuel will be an overriding consideration and that the early interplanetary tracks will keep as close to the absolute optimum

as may be possible, even though this involves a few years of waiting until the solar system has shuffled itself into a suitable arrangement! However, the problem of minimizing under conditions of specified time of transfer is obviously one of great importance and is recommended to mathematical readers for investigation.

Full details of the manner in which the equations given in the next section were obtained may be found in reference 5.

2. Fundamental Equations

We take polar coordinates $(1/u, \theta)$ in the plane of the two terminal orbits between which optimum transfer of the rocket is to be effected, the pole being at the centre of attraction. Any elliptical orbit in the plane then has the equation

$$u = p + q\cos(\theta + \gamma) \quad .. \quad .. \quad .. \quad (1)$$

where p, q, γ are constants determining the orbit. This orbit will be referred to as the orbit (p, q, γ). p is the reciprocal of the semi-latus rectum l of the ellipse. q is the ratio e/l where e is the eccentricity. γ is the anticlockwise angle measured from the nearer apse to the arbitrary reference line $\theta = 0$. We have $p > q > 0$. We shall always suppose motion around the orbit to be in the anticlockwise sense.

If (p_1, q_1, γ_1), (p_2, q_2, γ_2) are the terminal orbits, it is proved in reference 5 that optimum transfer is achieved by application of a number of impulsive thrusts. If the orbits intersect, they will do so in two points and a single impulse of appropriate magnitude and direction is evidently sufficient to effect transfer at either of these points. This mode of transfer will be considered in Section 3. However, although this mode of transfer corresponds to a mathematical stationary value for the fuel expenditure, it is not the absolute optimum mode in all cases of intersecting orbits and it does not apply to the case of most practical interest, viz., that of non-intersecting orbits. It is therefore necessary to consider the case of transfer by two impulses.

During the operation of the rocket jet, the elements (p, q, γ) of the orbit in which the rocket is moving will vary in a manner depending on the thrust programme, assuming that the direction of the thrust always lies in the plane of motion. During the short time of an impulsive thrust in this plane, these elements are related by the two equations

$$q\cos(\theta + \gamma) = u - p \quad .. \quad .. \quad .. \quad (2)$$

$$q\sin(\theta + \gamma) = (u - Ap^{\frac{1}{2}})\tan\phi \quad .. \quad .. \quad (3)$$

where u, θ, A, ϕ are constants depending on the direction of the impulse, etc. The physical significance of these constants is as follows:

(i) $(1/u, \theta)$ is the point at which the impulse is applied.

(ii) ϕ is the angle made by the direction of thrust with the perpendicular to the radius vector $1/u$ drawn in the same sense as that of the rotation of the radius vector as the rocket describes its orbit.

(iii) If μu^2 is the attraction per unit mass, $\mu^{\frac{1}{2}}A\sin\phi$ is the component of rocket velocity in the direction perpendicular to the thrust and which accordingly remains constant during the short time of this thrust.

If transfer is to be effected by the application of two impulsive thrusts, let $(u_1, \theta_1, A_1, \phi_1)$ determine the first impulse and $(u_2, \theta_2, A_2, \phi_2)$ the second impulse. Let (p, q, γ) be the elements of the rocket's orbit in the interval between these impulses, so that during the first impulse the elements change from (p_1, q_1, γ_1) to (p, q, γ) and during the second from (p, q, γ) to (p_2, q_2, γ_2). Application of equations (2) and (3) therefore gives the equations

$$\left.\begin{aligned}
q_1 \cos(\theta_1 + \gamma_1) &= u_1 - p_1 \\
q_1 \sin(\theta_1 + \gamma_1) &= (u_1 - A_1 p_1^{\frac{1}{2}}) \tan \phi_1 \\
q \cos(\theta_1 + \gamma) &= u_1 - p \\
q \sin(\theta_1 + \gamma) &= (u_1 - A_1 p^{\frac{1}{2}}) \tan \phi_1 \\
q \cos(\theta_2 + \gamma) &= u_2 - p \\
q \sin(\theta_2 + \gamma) &= (u_2 - A_2 p)^{\frac{1}{2}} \tan \phi_2 \\
q_2 \cos(\theta_2 + \gamma_2) &= u_2 - p_2 \\
q_2 \sin(\theta_2 + \gamma_2) &= (u_2 - A_2 p_2^{\frac{1}{2}}) \tan \phi_2
\end{aligned}\right\} \quad (4)$$

The transfer by this mode is minimal if, in addition, the following expressions are continuous from the end of the first impulse to the beginning of the next, i.e., take the same values at these instants,

$$\left.\begin{aligned}
&\left(\frac{u+p}{Ap^{\frac{1}{2}}} + 1\right) \cos \phi \\
&\left(1 + \frac{p^{\frac{1}{2}}}{A}\right)(u - p) \cos \phi + (u - Ap^{\frac{1}{2}}) \tan \phi \sin \phi \\
&\left(\frac{u}{A} - A\right) \sin \phi
\end{aligned}\right\} \quad (5)$$

This condition leads to the equations,

$$\left.\begin{aligned}
&\left(\frac{u_1+p}{A_1 p^{\frac{1}{2}}} + 1\right) \cos \phi_1 = \left(\frac{u_2+p}{A_2 p^{\frac{1}{2}}} + 1\right) \cos \phi_2 \\
&\left(1 + \frac{p^{\frac{1}{2}}}{A_1}\right)(u_1 - p) \cos \phi_1 + (u_1 - A_1 p^{\frac{1}{2}}) \tan \phi_1 \sin \phi_1 \\
&\quad = \left(1 + \frac{p^{\frac{1}{2}}}{A_2}\right)(u_2 - p) \cos \phi_2 + (u_2 - A_2 p^{\frac{1}{2}}) \tan \phi_2 \sin \phi_2 \\
&\left(\frac{u_1}{A_1} - A_1\right) \sin \phi_1 = \left(\frac{u_2}{A_2} - A_2\right) \sin \phi_2
\end{aligned}\right\} \quad (6)$$

Equations (4) and (6) being eleven in number, are sufficient to specify the eleven unknowns $p, q, \gamma, u_1, \theta_1, A_1, \phi_1, u_2, \theta_2, A_2, \phi_2$.

Optimum transfer via three impulses may be analysed in a similar fashion, the expressions (5) being continuous from the end of an impulse to the commencement of the succeeding impulse.

At any impulse (u, θ, A, ϕ), if m is the mass of the rocket before the impulse and m' is its mass afterwards, the fuel expenditure is given by

$$\mu^{-\frac{1}{2}} c \log \frac{m}{m'} = u(p'^{-\frac{1}{2}} - p^{-\frac{1}{2}}) \sec \phi \quad (7)$$

where p and p' are the initial and final values respectively of the rocket's orbital element p and c is the jet velocity.

To establish the absolute minimal mode of transfer, the one-, two-, three-, etc., impulse cases must be computed separately and the minimum selected. Experience suggests that two impulses usually lead to the absolute optimum solution.

3. Transfer by One Impulse

Consider a body moving in the orbit having equation (1). If r is the radius vector ($= 1/u$), we have by differentiation of equation (1) with respect to the time

$$\dot{r} = q r^2 \dot{\theta} \sin(\theta + \gamma) \quad .. \quad .. \quad .. \quad (8)$$

$r^2\dot{\theta}$ is twice the rate of description of area by the radius vector r, and is therefore a constant for the orbit. If h is this constant, it is well known that $h^2 = \mu l = \mu/p$. Hence equation (8) is equivalent to

$$\dot{r} = q\sqrt{\frac{\mu}{p}} \sin(\theta + \gamma) \quad .. \quad .. \quad .. \quad (9)$$

giving the radial component of velocity at any point in the orbit. To obtain the transverse component we have

$$r\dot{\theta} = h/r = \sqrt{\frac{\mu}{p}}u$$

$$= \mu^{\frac{1}{2}}\left\{p^{\frac{1}{2}} + \frac{q}{p^{\frac{1}{2}}}\cos(\theta + \gamma)\right\} \quad .. \quad .. \quad (10)$$

Suppose the orbits (p_1, q_1, γ_1), (p_2, q_2, γ_2) intersect at the point $(1/u, \theta)$. To transfer from one orbit to the other at this point, the radial component of velocity must be increased by

$$\mu^{\frac{1}{2}}\left\{\frac{q_2}{p_2^{\frac{1}{2}}}\sin(\theta + \gamma_2) - \frac{q_1}{p_1^{\frac{1}{2}}}\sin(\theta + \gamma_1)\right\}$$

and the transverse component by

$$\mu^{\frac{1}{2}}\left\{p_2^{\frac{1}{2}} + \frac{q_2}{p_2^{\frac{1}{2}}}\cos(\theta + \gamma_2) - p_1^{\frac{1}{2}} - \frac{q_1}{p_1^{\frac{1}{2}}}\cos(\theta + \gamma_1)\right\}$$

Squaring and adding these expressions and making use of the equations

$$u = p_1 + q_1\cos(\theta + \gamma_1) = p_2 + q_2\cos(\theta + \gamma_2),$$

we obtain for the square of the net velocity increment necessary for transfer the expression

$$\mu\left\{\frac{q_1^2}{p_1} + \frac{q_2^2}{p_2} - \frac{2q_1q_2}{p_1^{\frac{1}{2}}p_2^{\frac{1}{2}}}\cos(\gamma_1 - \gamma_2) - (p_1^{\frac{1}{2}} - p_2^{\frac{1}{2}})^2\left(1 + \frac{2u}{p_1^{\frac{1}{2}}p_2^{\frac{1}{2}}}\right)\right\}$$

If m and m' are the masses of the rocket before and after transfer, we have accordingly

$$\mu^{-\frac{1}{2}}c \log \frac{m}{m'} = \sqrt{\frac{q_1^2}{p_1} + \frac{q_2^2}{p_2} - \frac{2q_1q_2}{p_1^{\frac{1}{2}}p_2^{\frac{1}{2}}} \cos(\gamma_1 - \gamma_2) - (p_1^{\frac{1}{2}} - p_2^{\frac{1}{2}})^2 \left(1 + \frac{2u}{p_1^{\frac{1}{2}}p_2^{\frac{1}{2}}}\right)} \quad .. \quad .. \quad .. \quad (11)$$

To exemplify the use of this formula, consider the case of transfer between two orbits of identical shape and size, whose axes are inclined at an angle 2γ. Let the orbits be (p, q, γ) and $(p, q, -\gamma)$, i.e., have equations

$$u = p + q\cos(\theta + \gamma), \quad u = p + q\cos(\theta - \gamma) \quad .. \quad (12)$$

Solving simultaneously these equations, we find that the points of intersection are

$$\begin{array}{ll} u = p + q\cos\gamma & u = p - q\cos\gamma \\ \theta = 0 & \theta = \pi \end{array} \quad .. \quad (13)$$

Substituting in (11) the appropriate values at either point, we obtain,

$$\mu^{-\frac{1}{2}}c \log \frac{m}{m'} = \left\{\frac{2q^2}{p^2}(1 - \cos 2\gamma)\right\}^{\frac{1}{2}} = \frac{2q}{p}|\sin\gamma| \quad .. \quad .. \quad (14)$$

Evidently transfer is most costly when the two axes are in the same line, but in opposite senses.

A numerical example follows:

Example

Calculate the mass ratio necessary to effect transfer from the earth's orbit into that of the asteroid 1932 *HA, assuming a jet velocity of* 10 *km./sec.*

Taking the earth's orbit as circular and of radius one unit, its elements are $(1, 0, \gamma)$ (γ is indeterminate). The orbit of 1932 HA has semi-major axis 1·49 units and eccentricity 0·566. Its elements are accordingly (0·987, 0·559, γ'). At the two points of intersection $u = 1$ and hence by substitution in equation (11) we find that

$$\mu^{-\frac{1}{2}}c \log \frac{m}{m'} = 0{\cdot}563.$$

In units of secs. and of the astronomical unit of length we are employing, $\mu = 3{\cdot}96 \times 10^{-14}$ and $c = 6{\cdot}69 \times 10^{-8}$. Hence $m/m' = 2{\cdot}31$.

4. Transfer by Two Impulses

Equations (4) and (6) have now to be solved and the fuel expended then calculated from equation (7). The most satisfactory manner of dealing with these equations in any particular case is a subject for further research by workers familiar with the methods available for the numerical solution of equations. Direct methods seem doomed to failure and presumably some method of successive approximation will have to be employed. In certain cases however, the equations simplify considerably. The solution to the equations in the case of transfer between two circular orbits is given in reference (5) and proves to correspond to transfer via Hohmann's cotangential ellipse,[6] as might be expected.

Another case in which we may expect some simplification is that of transfer between the ellipses $(p, q, \pm\gamma)$. There being symmetry about the line $\theta = 0$, we may assume that the optimum two-impulse solution will also show symmetry about this line. Referring to the figure, OX is the line $\theta = 0$ and AB, $A'B'$ are the major axes of the two terminal ellipses (the figure has been drawn

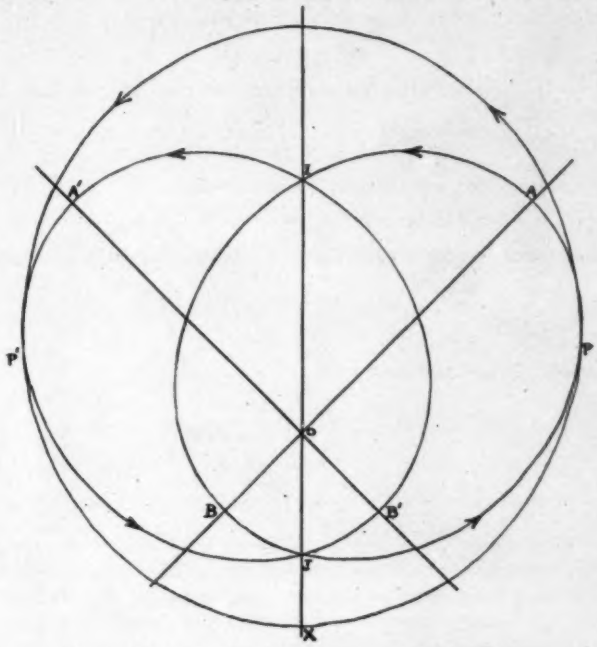

FIG. 1. Optimum transfer between two similar ellipses.

for the case $p = 1$, $q = 0{\cdot}5$, $\gamma = \pi/4$, considered in detail below). The trajectory of transfer will be a third ellipse $(p', q', 0)$, having its axis in the direction of OX, and intersecting the terminals in two points P and P', symmetrical with respect to OX. An impulse is applied at P to bring the rocket into the orbit of transfer and a second impulse is applied at P' to bring it into the final orbit. If (u, θ, A, ϕ) characterize the impulse at P, it is clear from the symmetry that $(u, -\theta, A, \pi - \phi)$ similarly characterize the impulse at P'. Omitting repetitions of equations and identities, we find that equations (4) and (6) now take the form

$$q \cos(\theta + \gamma) = u - p \quad .. \quad .. \quad .. \quad .. \quad (15)$$

$$q \sin(\theta + \gamma) = (u - Ap^{\frac{1}{2}}) \tan\phi \quad .. \quad .. \quad (16)$$

$$q' \cos\theta = u - p' \quad .. \quad .. \quad .. \quad .. \quad .. \quad (17)$$

$$q' \sin\theta = (u - Ap'^{\frac{1}{2}}) \tan\phi \quad .. \quad .. \quad .. \quad (18)$$

$$\left(\frac{u+p'}{Ap'^{\frac{1}{2}}}+1\right)\cos\phi=0 \quad .. \quad .. \quad .. \quad .. \quad (19)$$

$$\left(1+\frac{p'^{\frac{1}{2}}}{A}\right)(u-p')\cos\phi+(u-Ap'^{\frac{1}{2}})\tan\phi\sin\phi=0 \quad .. \quad (20)$$

i.e., six equations to be satisfied by the six unknowns p', q', u, θ, A, ϕ.

Assuming that $\cos\phi \neq 0$, we obtain from equation (19)

$$A/p'^{\frac{1}{2}}=-(x+1) \quad .. \quad .. \quad .. \quad (21)$$

where $x=u/p'$. Substituting for $A/p'^{\frac{1}{2}}$ in equation (20), we now find that

$$\tan^2\phi=\frac{x(1-x)}{(x+1)(2x+1)} \quad .. \quad .. \quad .. \quad (22)$$

Squaring and adding equations (17) and (18) we have

$$q'^2=(u-p')^2+(u-Ap'^{\frac{1}{2}})^2\tan^2\phi \quad .. \quad .. \quad (23)$$

Substituting for A and $\tan\phi$ from the previous two equations in equation (23) gives

$$y^2=(1-x^3)/(1+x) \quad .. \quad .. \quad .. \quad (24)$$

where $y=q'/p'$.

Equations (17) and (18) now yield

$$\cos\theta=-\sqrt{\frac{1-x^2}{1+x+x^2}} \quad .. \quad .. \quad .. \quad (25)$$

$$\sin\theta=\sqrt{\frac{x(2x+1)}{1+x+x^2}} \quad .. \quad .. \quad .. \quad (26)$$

where we have taken $\tan\phi$ and y positively from equations (22) and (24) respectively. Evidently there are four possible combinations of signs and each may be considered separately in the same manner as the case we have chosen. Numerical calculation shows, however, that this latter case leads to the absolute optimum solution.

Putting $q\cos\gamma/p=P$, $q\sin\gamma/p=Q$, we find that equations (15) and (16) may now be written in the form

$$xz^2=1-\frac{P(1-x^2)^{\frac{1}{2}}+Q\{x(2x+1)\}^{\frac{1}{2}}}{(1+x+x^2)^{\frac{1}{2}}} \quad .. \quad .. \quad (27)$$

$$z\left(\frac{x}{1+x}z+1\right)=\sqrt{\frac{2x+1}{x(1+x)(1-x^3)}}\left[P\{x(2x+1)\}^{\frac{1}{2}}-Q(1-x^2)^{\frac{1}{2}}\right] \quad (28)$$

where $z=(p'/p)^{\frac{1}{2}}$ and is essentially positive.

P and Q being given, equations (27) and (28) may be solved approximately by plotting z as a function of x from each equation and determining the point of intersection of the graphs. A more accurate solution may then be obtained by a process of linear interpolation. Elimination of z between these two equations is easily accomplished, but results in an equation for x which is not suited to numerical computation.

We will perform the calculation which has been suggested in the particular case when $p = 1$, $q = 0{\cdot}5$ and $\gamma = \pi/4$. In this case the axes of the terminal ellipses are perpendicular and $P = Q = 0{\cdot}3536$.

A graphical solution of the equations (27) and (28) suggests that $x = 0{\cdot}9$, $z = 0{\cdot}75$. Taking $x = 0{\cdot}9$ and $0{\cdot}92$, we determine z accurately from equations (27) and (28) to take the values shown in the table below:

x	z (eqn. (27))	z (eqn. (28))
0·9	0·793	0·740
0·92	0·789	0·834

Linear interpolation from this table gives an improved approximation to the solution, viz., $x = 0{\cdot}911$, $z = 0{\cdot}791$. Using $x = 0{\cdot}911$, $0{\cdot}912$ as trial values and repeating the process of interpolation, we obtain as the final solution $x = 0{\cdot}9115$, $z = 0{\cdot}7907$.

Making use of equations (21) to (26), we obtain the values of all the quantities we have introduced, viz.,

$$\left.\begin{array}{ll} p' = 0{\cdot}6252, & q' = 0{\cdot}2228 \\ u = 0{\cdot}5698, & \theta = 104^\circ\,24' \\ A = -1{\cdot}511 & \phi = 6^\circ\,58' \end{array}\right\} \quad .. \quad .. \quad (29)$$

Substituting appropriately in equation (7) for each impulse, we obtain for the mass ratio R corresponding to this manoeuvre, the equation

$$\mu^{-\frac{1}{2}} c \log R = 0{\cdot}3043 \quad .. \quad .. \quad .. \quad (30)$$

Reference to the figure reveals that the ellipse of transfer is very nearly tangential to the terminal ellipses and it is therefore suggested that we should compare the optimum fuel expenditure just calculated, with that corresponding to transfer via a tangential ellipse. There is an infinity of such ellipses, but selecting that which leads to maximum fuel economy, we calculate that the mass ratio R' is given by the equation

$$\mu^{-\frac{1}{2}} c \log R' = 0{\cdot}3113 \quad .. \quad .. \quad .. \quad (31)$$

It will be seen that this tangential ellipse is a good approximation to the optimum solution. If $R = 2$, for example, the fuel wastage involved in a transfer via the tangential ellipse is 16 per cent. For larger mass ratios, the percentage wastage is, of course, correspondingly greater. However, as a first approximation to the optimum solution, the best tangential ellipse has been found very satisfactory in all cases which have been computed and it is therefore important to have available a method of arriving at this ellipse and the corresponding value of $\mu^{-\frac{1}{2}} c \log R'$. Such a method has been evolved and will be described in a later paper.

Single impulse transfer at either of the points of intersection I or J of the two terminal ellipses may be achieved at a cost specified by the equation $\mu^{-\frac{1}{2}} c \log R'' = 0{\cdot}7071$, R'' being the necessary mass ratio. This mode of transfer is evidently exceedingly wasteful of fuel.

5. Further Research

Further investigation of the problem of optimum transfer might usefully seek to answer the following questions:

(i) How may the method of this paper be extended to deal with transfer between two non-coplanar orbits? Characterizing an orbit by five elements instead of three, there should be no difficulty in generalizing the argument of reference (5) to prove that optimum transfer will be effected by application of a series of impulses. The conditions to be satisfied by these impulses must then be discovered.

(ii) Employing transfer by the best tangential ellipse as a first approximation to the optimum mode, how may this approximation be improved in the general case to obtain the required solution of equations (4) and (6)?

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"FLYING SAUCERS"

The recent revival of reports of the above nature has culminated in a long and carefully-documented feature printed in *Life* for April 7 (the article was not used in the international edition). Since *Life* is a soberly reliable and responsible journal, such a detailed survey, of course, merits some attention, and certainly the recurrence of "saucer phenomena," whether objective or subjective, is a most puzzling thing.

After stating that the U.S.A.F. has alerted its personnel for interception of any new "saucers," and requested any observers of such objects to contact their Air Technical Intelligence Center at Wright Field, *Life* quotes several scientific authorities who believe in the real nature of the phenomena, and concludes:—

"Out of this exhaustive enquiry these propositions seem firmly shaped by the evidence:

(1) Disks, cylinders and similar objects of geometrical form, luminous quality and solid nature for several years have been, and may be now, actually present in the atmosphere of the Earth.
(2) Globes of green fire also, of a brightness more intense than the full Moon's, have frequently passed through the skies.
(3) These objects cannot be explained by present science as natural phenomena—but solely as artificial devices, created and operated by a high intelligence.
(4) Finally, no power plant known or projected on Earth could account for the performance of these devices."

While conceding the impressive nature of the array of evidence submitted in the *Life* feature, the B.I.S. still remains unconvinced that this planet is already in contact with extra-terrestrial forces—a fair statement would be to say that we retain an open mind, tinged with scepticism! This in spite of the fact that we should rather *like* to believe that spaceships were already flying in the neighbourhood of the Earth, even if they were not our own—and in spite of the fact that, of course, we would be the last to ridicule such a possibility.

The reasons for our attitude may briefly be summarised as follows:—

(*a*) It is surely, to say the least, suspicious that most (admittedly not all) saucer reports emanate from a country where science-fiction (of the pulp-magazine and comic-strip variety) is extremely popular—and at a time when the vogue for such literature is even increasing. We do not mean this in any derogatory sense; impressionable people exist in all countries, but in different places and at different times, they "see" different things. (For example, in Central Europe a century ago, people "saw" vampires.)

(*b*) Some of the observers of "saucers" were not impressionable people —they were scientists, airline pilots, and so on, as reported by *Life*. However, it really is not too difficult even for intelligent observers to mistake, in all good faith, what they see. Natural phenomena, balloons and aeroplanes in unusual attitudes or conditions of lighting —all can appear, on occasion, as very unusual objects. Some "saucer-sightings" have been explained on such grounds; it is very difficult to dispose of a good many of the stories this way, and of some it is impossible. However——

(*c*) We would not yet be prepared to rule out the further possibility that some of the "observers" were enjoying a large practical joke at the expense of their fellow-men!

(*d*) The objects which are alleged to have been seen display a disturbing variety among themselves—suggesting that no single explanation would fit all cases.

A few B.I.S. members have written to say that they think we are unwise to adopt a merely flippant and disbelieving attitude towards "flying saucers." Perhaps they will be happier if we assure them that this attitude is merely reserved for *some* of the reports and books which have appeared on the subject. Others (such as the *Life* feature) we are much more inclined to take seriously, and, at any time, we are open to be convinced.

Especially if we ever happen to see a flying saucer ourselves. . . .

As we go to press, Washington is again suffering from a plague of flying saucers on its radar screens, and the number of sightings over the U.S. as a whole has appeared to reach an all-time high. Jet fighters vectored into the radar echoes have found nothing there, and it appears fairly certain that the phenomenon is the well-known "radar mirage."

Under certain conditions, particularly where the normal temperature gradient in the atmosphere is reversed, strong echoes can be obtained from ground objects at great distances, and, as in the case of the ordinary optical mirage, these radar echoes will appear projected in the sky.

NORTH-WESTERN BRANCH EXHIBITION

An exhibition organized by the North-Western Branch of the Society opened in Manchester on Wednesday, April 16, at the Adult Education Institute. The exhibition featured the *Daily Express* astronautical panels which were shown at the London Congress, together with other similar exhibition material and two working models supplied by the Branch.

One of these models was a device which has been often suggested in the literature, i.e., the gravitational field model. This consisted of a model rotating Earth in a scientifically proportioned bowl, into which a steel sphere was projected at regular intervals with a predetermined momentum, which caused it to follow a hyperbolic grazing orbit. This worked continuously during the exhibition, but periodically officials used it to demonstrate other types of orbits.

Undoubtedly the main attraction of the exhibition was the lunar rocket take-off and landing demonstration, made at half-hour intervals on the main stage. It consisted of a model rocket built to a scale of about 1/300 which represented a hypothetical interplanetary spaceship as it might have been seen from a point half a mile away from the launching area. The model was activated by a form of Attwood's machine designed to give an acceleration of about $1/200\,g$, the correct proportion of acceleration which the real rocket would develop. As previously mentioned this demonstration took place on the stage and its realism was immeasurably enhanced by the modern professional-type stage lighting and other effects which are rarely available other than in the theatre. The Adult Education Institute are to be thanked for making all this equipment available.

As the curtains opened, the audience in the auditorium were able to see the graceful silver lines of the spaceship illuminated by the beam of a single spotlight against a representation of the terrestrial sky. No part of the raising mechanism could be observed. After a suitable description of the demonstration had been given by a recording, the audience were carried in their imagination through the take-off procedure until, with suitable sound effects, the rocket rose slowly but with increasing velocity until it disappeared from view at the top of the proscenium. After a brief interval during which the lighting effects were altered to give a representation of the lunar surface with star-fields shining in a darkened sky, the rocket decelerated silently, finally coming to rest on its hydraulic jacks.

An information bureau was available throughout the exhibition where visitors' enquiries were satisfied. The exhibition was opened from 11.0 a.m. to 9.30 p.m. each day and on the closing day, Saturday, April 19, two film shows were given between 2.15 and 5.15 p.m. Slides were shown advertising the exhibition at those cinemas in the area showing the film *The Day the Earth Stood Still*, and there was a reasonable coverage by the local and national press.

Mr. Armstrong explains meaning of escape velocity to visitors.

About 2,000 people attended the exhibition and a further 500 attended the two film shows. Peak attendances were from 12 noon to 2.30 p.m. when the exhibition was always crowded.

A number of short lectures on interplanetary flight and high altitude research were recorded and these were played at frequent intervals, together with announcements concerning the activities of the Society.

Many people made themselves known at the information desk, including visitors from the University staff, the aeronautical, and electronic industries in the area. Literature regarding the Society was in great demand and an S.O.S. had to be sent to London to replenish the stocks.

Acknowledgements

The *Daily Express*, who provided and erected the greater part of the material.

The Manchester Education Committee and Mr. Burney, Warden of the Adult Education Institute, for making the hall available and for the almost unbounded facilities which contributed to the success of the exhibition.

Mr. C. A. Cross and Mr. G. Redman for the design, construction and maintenance of the working models.

Mr. M. A. Browne for the recordings, sound commentary and effects used in the spaceship demonstration and throughout the exhibition.

Mr. E. Burgess for the lectures.

Mr. Armstrong and Mr. Good and other local members for attendance throughout the period of the exhibition.

NOTES AND NEWS

Nominations for Council, 1952/53

In accordance with the provisions of Article 15 of the Society's Constitution, one-third (i.e., *four*) members of the Council will retire from office at the Seventh Annual General Meeting, which will be held on Friday, December 5, 1952, at the Kent Room, Caxton Hall, London, S.W.1.

Nominations are invited from members for election to the Council for next session.

Signed nominations should be forwarded to the Secretary as soon as possible, and in any event, not later than October 24, 1952.

Voting papers will be prepared and forwarded to all members for completion and return before the date of the meeting.

The Chemical Exploration of the Stratosphere

In the Hugo Muller lecture to the Chemical Society (Manchester, April 23) Prof. F. A. Paneth described the work carried out at Durham on samples of air from the stratosphere. The samples were obtained during two "Aerobee" flights in December, 1950, and September, 1951. They were received in England in the original steel bottles which had been automatically opened and resealed during the rocket ascents. Each bottle contained less than half a cubic centimetre of air at atmospheric pressure. It was found possible to obtain an analysis for helium, neon, nitrogen and argon on a volume of less than 1/10 of a cubic centimetre. The air at ground level contains 5·24 parts of helium and 18 parts of neon per million parts, and 0·94 per cent. of argon. The gases were separated by fractional absorption on active charcoal, and the amounts of the fractions measured by determining their pressures with a Pirani gauge. By these techniques it was possible to separate one millionth of a cubic centimetre of helium from a tenth of a cubic centimetre of air, and to measure it to an accuracy of 1 per cent.

The analysis of samples from 50 to 70 Kms showed that up to 57 Kms the atmosphere was uniformly mixed. Above this level the helium and neon content was progressively increased and the argon content reduced. These changes could only be caused by gravitational separation, but this process had not been carried to the equilibrium for completely still air. Much further sampling and analysis would be needed to establish the nature of the slow mixing processes, and the work was continuing.

Planetarium Space Travel Show

During the past four years, the Griffith Observatory, Los Angeles, has presented a space travel show entitled "A Trip to the Moon" (see *J.B.I.S.*, **9**,281).

Each year the show has been improved upon by the addition of more and better apparatus, and it has now been decided that the title be altered to "We Land on the Moon."

The show begins with a sunset on Earth and a night among the stars. Later the scene moves to the equator, where, from a tropical island, the space ship is to leave. The ship blots out the stars as an imaginary entrance is made, and

after take-off, the Moon grows gradually until it fills the whole of a "window" 25 feet in diameter. After that it continues to enlarge until, if all could be seen at one time, it would have a diameter of some 150 feet!

When a close approach has been made to its surface, the various lunar formations can be seen passing underneath, mountain ranges, walled plains, etc., which are accompanied by a running commentary on their possible origin.

When the journey over the lunar surface has been completed, the ship is turned to bring the Earth into view, where it appears as almost four times the diameter of the Moon as seen from the Earth. The Earth can be seen rotating, and also shows similar phases to that exhibited by the Moon. During this time, the rocket is deemed to be landing in the crater Copernicus, 56 miles in diameter.

The landing accomplished, the audience then see a reconstruction of the scene which might face the actual travellers, i.e., the crater wall of rugged mountains, and the Earth, Sun and stars in a jet-black sky. After examining the crater, the party return to the ship and watch the Moon as it recedes during the trip back to Earth.

The spectacle described is produced jointly by the Zeiss planetarium and seven additional projectors which exhibit the space travel scenes. These extra projectors are not auxiliaries to the planetarium, but form major instruments invented and built at the Griffith Observatory at a cost of about $15,000.

The new feature of landing on the Moon was produced with the aid of a 12-foot model of the crater, built up from an examination of the best possible photographs, taken under all manner of illuminations.

Astronautical Societies

Since the last International Astronautical Congress, held under B.I.S. auspices in London last September, rocket or interplanetary societies have been officially established in several more countries; in several cases, the bodies concerned were known to be in process of organisation last year, but now they have attained the status of formal societies, which presumably may be incorporated in the I.A.F. at the next Congress. It is hoped that this will be so, and also that the membership in the I.A.F. will be confirmed of those societies which, although in existence last September, were not represented at the London Congress, either personally or by proxy.

Apart from the Dutch Society for Space Travel at The Hague (see March *B.I.S. Journal*, p. 88), there is now a Japanese Rocket Society, and a new German one—the Gesellschaft fur Raketenforschung, of Bremen, under the leadership of Albert Pullenberg, Karl Poggensee, and Rudolf Nebel. We understand that the N.W. and S.W. G.f.W.'s have been dissolved and their members recommended to join the Stuttgart Society. Also (to the best of our knowledge and belief) the V.A.A., of Liepzig in the Eastern Zone, has ceased to exist. It proved unsuccessful in its attempts to obtain sanction for its legal incorporation from the Russian authorities.

We are also unaware of any recent publications or activity on the part of the Canadian and United States Rocket Societies.

Fellowship Requirements

In accordance with the provisions of Article 22 (which authorizes the Council to make and amend Bye-Laws), a resolution has recently been approved requiring that all applicants for election to Fellowship in accordance with Bye-Laws 6 (*d*), (*e*) and (*f*), shall not be less than 25 years of age.

International Fantasy Award

The International Fantasy Award for 1952 in the non-fiction field has been given to Mr. A. C. Clarke for his book, *The Exploration of Space*.

The first award (for 1951) was given jointly to Willy Ley and Chesley Bonestell for their book *The Conquest of Space*.

The award is a beautifully constructed table ornament comprising a model spaceship 14 in. in height, with a globular cigarette lighter at its base and a hand-engraved inscription plate mounted on a wooden plinth.

The trophy is made of copper bronze and stands on a mahogany base.

From the World's Press

Beginning with their December, 1951, issue, the *Atlantic Monthly*, of Boston, U.S.A., printed two very interesting articles by J. W. Angell on German war-time guided missile development. Of particular interest is the account given of the history of the Peenemunde establishment, with special reference to its political troubles; all this is based on the manuscript of a forthcoming book ("V.2: The Story of a Great Weapon") by General Dornberger, the Army commandant of Peenemunde, who is now working in the U.S., reportedly with Bell Aircraft. After describing the basis of the German rocket weapon work in the activities of the V.f.R. and Prof. Oberth, the article goes on to describe the beginning of serious military research at Kummersdorf in 1931. Here General (then Captain) Dornberger first met the young von Braun, later to be Technical Director at Peenemunde under him.

Each member of this fruitful partnership was an enthusiast for the idea of space flight; Angell says: "The hard-headed captain and the blue-eyed wonder-boy became, with the help of capable and loyal assistants, not only the true progenitors of the ideal long-range weapon, but, in all likelihood, the actual forerunners of 'the journey into space'. . . . There is some substance in the charge later brought by antagonists in the Army and the S.S., that both Dornberger and von Braun were guilty of having used huge sums of military funds as a means of fostering their planetary and interstellar goals." It would appear that, in both their nominal military objectives and in their personal ambitions to deflect these towards more astronautical ends, the pair found little encouragement from Hitler; even his belated enthusiastic support was embarrassing when it came. As for Goering, he never saw a V.2 firing until 1944, when he bellowed: "This is colossal! We must fire one at the first Nuremberg post-war Party Rally!" Von Brauchitsch and Speer were, however, more sober and far-sighted in their judgment, and helped the Peenemunde organisation in every possible way throughout.

We reprint the following pungent observation from "Hyperion's" column in *The Local Government Service*:—

> When, on a slow and dirty train in New England, I first picked up *Planetary Comics*, I made the interesting discovery that on every planet —those known to mere science and the many more known to comic science —the climate, the flora and fauna, and the political organisation might differ, but there was always a supply of shapely young women in exiguous two-piece garments.—D. W. BROGAN.

. . . while the "Homo Sapiens" feature of *Picture Post* reproduced this delightful deadpan quotation from *The Braintree and Witham Times*:—"During the discussion which followed, Dr. Morton said that some of the products of modern scientific achievements were like firearms in the hands of children. The human race might be partially destroyed by them but there would be sufficient survivors to carry on to even greater scientific progress."

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The Liars' Club of Burlington, Wisconsin, awarded a free trip to the Moon (together with a part interest in the Pacific Ocean) to those of its members who told this year's prize tall stories.

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The December (Christmas) issue of the Bristol Aeroplane Co.'s house magazine slightly modified its title to *The Bristol (P.) Review* and foreshadowed such products from the firm in A.D. 2051 as the Astrazon I, the Astrofreighter, the 1075 Astroliner, and the Bristol "Bogus" rocket motor. By that time, it was suggested, the British Interplanetary Spaceways Corporation might be hoping to reduce its last-year deficit of £18,000 million by at least £8,000 million, even though "appalled" at the prospect of having to operate the Astrazon, with its 1,102 passengers, non-stop to Mars.

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Britain and the U.S.A. have signed an agreement permitting the extension of the Bahamas long-range proving ground for guided missiles all the way to the Cocos Islands, from the launching base in Florida, it was reported in January.

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The Daily Telegraph last December reported that U.S. Naval research workers are experimenting with a gun using hydrogen as a propellant, designed to give its projectiles a muzzle velocity of four miles per second, in order to conduct tests on aerodynamic heating and resistance at ultra-high speeds of flight.

* * * *

Further to the previous announcements regarding General Electric and Convair, it has recently been announced that the U.S. Air Force have now placed contracts with Pratt and Whitney for "a different type" of atomic aircraft engine, and with Boeing for an airframe to take it.

The issue of *Collier's* for March 22, 1952, contains what is probably the most ambitious treatment of astronautics yet made by any popular journal. Fifteen pages are devoted to specially commissioned articles and to very fine paintings by Chesley Bonestell, Rolf Klep and Fred Freeman. A panel consisting of Dr. Wernher von Braun, Dr. Fred L. Whipple, Dr. Joseph Kaplan, Dr. Heinz Haber and Willy Ley worked with *Collier's* for five months on the project, and the resulting symposium is of great interest and value. It must count as a major landmark in the "popularisation" of astronautics.

The whole feature is entitled "Man Will Conquer Space *Soon*" and opens with an editorial headed "What Are We Waiting For?" (Answer: 4,000,000,000 dollars!) The first paragraph of the editorial is worth quoting as a proof of how far astronautics has progressed in the last 10 years: "On the following pages *Collier's* presents what may be one of the most important scientific symposiums ever published by a national magazine. It is the story of the inevitability of man's conquest of space."

The symposium opens with an article by Dr. von Braun, "Crossing the Last Frontier." This gives the basic ideas of the step-rocket and artificial satellites: it is illustrated by magnificent paintings of the space-station by Bonestell, and of a three-step rocket ship by Klep (based on von Braun's designs). There is also a somewhat hair-raising Bonestell picture of the space-ship glowing a dull red as it returns through the atmosphere.

This is followed by a short article about the space-station, written by Willy Ley and illustrated by Fred Freeman. The design shown is the "cart-wheel" type, which has much to recommend it if rotational gravity is to be used.

This is followed by an article by Dr. Whipple on the astronomical advantages of the space-station, entitled "The Heavens Open" and illustrated by a very fine Bonestell painting showing a "deep-space" type of ship passing across the face of the Moon. Dr. Joseph Kaplan in "This Side of Infinity" discusses the characteristics of the earth's atmosphere, and in "Can We Survive in Space?" Dr. Heinz Haber describes the physiological problems involved in astronautics. The symposium concludes with an article by Oscar Schachter, "Who Owns the Universe?" and a "Space Quiz" in which the panel of experts answers questions put to them.

As would be expected, the articles are technically accurate, but many will disagree with the stress that is placed on the possible military advantages of the space-station—or, even if they agree that they exist, will deplore their emphasis. Apart from this point, the symposium as a whole could hardly be bettered.

* * * *

Prof. Kirill Andreev, writing in a Moscow newspaper during February, made a series of predictions about astronautics in an article called "Astronomy of To-day and To-morrow." These closely paralleled the pronouncements with which we have become familiar in the western world, since he envisaged space-station observatories, atomic rocket motors and television surveys of planetary surfaces, all of which would bring about a revolution in astronomy. A Red revolution, of course.

The January 14 issue of *Aviation Week* reported that the Russians now have Peenemunde back in full operation, with additional new test facilities in operation and a defence force of armed trawlers, fixed land-based A.A. guns, and a group of 80 Mig. 15's. Missiles currently under development were stated to be:—

(*a*) The ground-to-air "Wasserfal," 40 of which had been fired by the Germans at the war's end (8,500 lb. wt., 25 feet long × 3 feet diameter, nitric acid and amine propellants, Mach. No. = 3.0).
(*b*) The A.5 control research model for A.4 (or V.2), using a "cold" peroxide motor.
(*c*) The A.9, winged version of A.4, with range extended by gliding to 500 miles.
(*d*) A new missile of the V.2 type, alleged to have a light blue exhaust flame.

Notwithstanding all this activity, the main missile development centre of the U.S.S.R. was stated now to be at Kaliningrad (formerly Koenigsberg), about 55 miles north-east of Berlin.

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The same magazine, on February 25, listed *some* (!) of the military missile projects currently being developed in the U.S.A., and which it was now possible to mention, viz.:—

(i) Terrier = ship-to-air, from Johns Hopkins Laboratory
(ii) Sparrow = air-to-air, from Sperry Co.
(iii) Nike = ground-to-air, from Bell Telephone and Douglas Aircraft Cos.
(iv) Matador (B.61) = ground-to-ground, turbojet, pilotless aircraft, from Martin.
(v) Snark = as (iv), from Northrop.
(vi) Hermes = ground-to-ground rocket, from General Electric. (There have also been reports of a similar weapon, called Corporal E, from Douglas.)
(vii) Loki = ground-to-air barrage weapon, from Bendix Corporation.
(viii) Rascal = air-to-air rocket, from Bell Aircraft, who are also working on the "Shrike."
(ix) Lark = ground-to-air rocket, from Fairchild.

In considering the above list, it should be remembered that it excludes research missiles such as Viking and Aerobee, also that military security is unlikely to release even the names and general descriptions of the latest and most important projects.

* * * *

Sympathetic articles on astronautics continue to crop up throughout the World's Press, in the most diverse sources. One of the strangest (to which we were recently asked to supply any possible news material) is the *Space Explorer*—a publicity magazine "sponsored by GORDON'S—that Good Bread with the Home Baked Flavour"!

This was in the U.S.A., of course. From the same country, but from less surprising journals, came recently an excellent series of no less than 15 articles in *The Christian Science Monitor*, and two (based on an interview with Dr. Krafft Ehricke, one of von Braun's assistants at Peenemunde, and now again at the U.S. Army's Redstone Arsenal) compiled by the International News Service and printed in *The New York Journal-American*.

Similarly, statements of belief in the feasibility of space-flight continue to be made by prominent personalities in the worlds of science and aviation. Our own Peter Masefield told Belfast schoolboys in January that he thought it would be possible to fly to the Moon by 1980, while just before this Major Alexander de Seversky had predicted in Buffalo that atomic rocket-propelled space-ships would be flying to the Moon in 3¼ hours within the next 50 years. According to the *Ottawa Citizen*, Wing Commander C. B. Limbrick, Head of the R.C.A.F. Guided Missives (sic!) Division, was more cautious, and merely prophesied pilotless trips from the Earth to the Moon "in the not-too-far future." Dr. Levitt of the Fels Planetarium in Philadelphia also believed in lunar space-ships, but thought the first one would cost about 200,000,000 dollars to build.

* * * *

The Jewish Observer for May 30 gave some interesting details of an excursion by the Egyptian Government into the field of guided missile development. Apparently, in 1951, the German firm of Physikalische Arbeitsgemeinschaft built up an organization in Egypt, with a staff of several German rocket specialists, including Drs. Fuellner, Dangguth, Stoetzer, and a Herr Pitzken. A "new-type missile" was developed, and made its first successful flight on October 31, 1951. Following this, trouble seems to have developed, when the Egyptians tried to take over the undertaking completely. Pitzken entered the Government service, it is reported, but Stoetzer was arrested and deported, while Fuellner sued for £3,500 compensation—according to another report in the paper *Dawn*, of Karachi (Pakistan). The latter source, quoting Dr. Kurt H. Fuellner in an interview (given after his return to W. Germany), said the biggest missile developed was only 5 ft. long, with a range of 10 or 20 miles—"But the British needn't worry. I don't believe the Egyptians can master the technique of these weapons on their own. . . . I'm finished with the Middle East."

Addendum

It is regretted that the headings on the second table, page 134, of the May *Journal* were inadvertently reversed. The table "Mars in Conjunction" refers to the values when Mars is at Opposition, and similarly the table headed "Mars at Opposition" should be amended to read "Mars in Conjunction."

Acknowledgement

The Council wishes to acknowledge with grateful thanks the receipt of 45 lantern slides, kindly donated by Mr. C. R. Armstrong to the Society's collection.

ABSTRACTS

Edited by J. HUMPHRIES

Abbreviations of titles of journals were given in the May, 1950, issue of the *Journal*, and addenda have appeared in subsequent issues. The following is a further addendum to the list.

Artill. Tidskr.	Artillerie Tidskift.
Schweiz. Astronaut. Arb.-Bull.	Schweizerische Astronautische Arbeitsgemeinschaft—Bulletin.
Trans. Faraday Soc.	Transactions of the Faraday Society.

Many of the articles noted are available on loan to members resident in the British Isles. Requests should be addressed to J. Humphries, 97, Churchill Avenue, Southcourt, Aylesbury, Bucks.

AERODYNAMICS

(250) **Aerodynamics of take-off and landing of the satellite rocket.** H. KUEHME. *Weltraumfahrt* (2), 53-59 (*April*, 1952). (*In German.*)
General investigation and calculation of aerodynamic forces. An example of take-off, return and landing of a satellite rocket project is given.

AIRCRAFT

(251) **Rockets for aircraft propulsion.** S. ALLEN. *Aeroplane*, **81**, 726-727 (*7th Dec.*, 1951).
Discussion of various propellants.

(252) **Rocket refueller.** *Flight*, **61**, 446 (*11th April*, 1952).
Description of liquid oxygen tanker for Bell X-1.

(253) **Fastest and highest.** *Flight*, **61**, 556-558 (*9th May*, 1952).
Supersonic flight experiences, mainly with the Skyrocket.

ASTRONAUTICS

See also abs. no. 250.

(254) **A method of interplanetary navigation.** C. OESTERWINTER. *Nordwestdeutsche Gesellschaft für Weltraumforschung Report No.* 2, 1-3 (*March*, 1951). (*In German.*)

(255) **Possibilities of communication with space-ships.** G. VON SCHRUTKA-RECKTENSTAMM. *Nordwestdeutsche Gesellschaft für Weltraumforschung Report No.* 2, 3-4 (*March*, 1951). (*In German.*)
Use of modulated light-beams.

(256) **Atlas of particular flight-paths of a rocket aircraft to and from a satellite station.** E. SÄNGER. *Nordwestdeutsche Gesellschaft für Weltraumforschung Report No.* 3, 95 pp. (*April*, 1951). (*In German.*)
Characteristics of flight paths for various exhaust velocities and mass ratios. All results plotted in a set of 50 graphs.

(257) **Will Russians build a Moon rocket?** H. KÖLLE. *Weltraumfahrt* (1), 9-11 (*Jan.*, 1952). (*In German.*)
Estimate of the possibilities of a Soviet Moon rocket project.

(258) **Movement of a space station in an elliptical orbit, inclined to the equator.** H. KRAUSE. *Weltraumfahrt* (1), 17-25 (*Jan.*, 1952). (*In German.*)
Fundamental equations for the calculation of the orbit. It is assumed that deviations from an accurate circle always will occur because of perturbations.

(259) **Tidal forces on the space station.** W. SCHAUB. *Weltraumfahrt* (1), 1-8 (*Jan.*, 1952). (*In German.*)
The tidal forces on the station in space cause conditions which possibly cannot be observed during erection in the orbit. It seems to be questionable if a space station with movable masses aboard can be stabilized in its orbit permanently.

(260) **Satellite rockets.** K. W. GATLAND, A. M. KUNESCH and A. E. DIXON. *Flight*, **61**, 150-152 (*8th Feb.*, 1952).
Paper delivered at the Second International Congress on Astronautics. [See *J. Brit. Interplanet. Soc.*, **10**, 287-294 (*Nov.*, 1951).]

(261) **The cost of interplanetary cargo transportation. Pt. II.** N. BOWMAN. *J. Space Flight*, **4**, (4), 1-9 (*April*, 1952).

(262) **Diagrammatic method for estimating the optimum fundamental data for the construction of space vehicles.** H. KÖLLE. *Weltraumfahrt* (2), 39-41 (*April*, 1952). (*In German.*)

(263) **Thoughts of an astronomer on astronautics.** W. SCHAUB. *Weltraumfahrt* (2), 34-38 (*April* 1952). (*In German.*)
The space ship will never be a vehicle for pleasure-trips through space. Astronautics involves many more problems than generally considered.

(264) **Interplanetary communications and navigation.** J. ELLIOTT. *J. Space Flight*, **4**, (5), 1-6 (*May*, 1952).

(265) **How far are we from space flight?** F. C. DURANT. *Aviation Wk.*, **56**, 25-26, 29-30, 33, 35 (*26th May*, 1952).
General review of the technical problems involved.

(266) **Orbital motion of a space station in an elliptical orbit, inclined to the equator.** H. KRAUSE. *Weltraumfahrt* (3), 74-79 (*July*, 1952). (*In German.*)
Horizontal projection of the elliptical path, field of vision and rate of lighting of the space station.

(267) **Possibilities of transition from elliptical into circular orbit and vice versa.** W. SCHAUB. *Weltraumfahrt* (3), 81-86 (*July*, 1952). (*In German.*)

ASTRONOMY

(268) **Recent phenomena on Mars.** T. SAHEKI. *Strolling Astronomer*, **6** (*April*, 1952).
An account of a strange white patch observed by several Japanese astronomers, considered by Saheki as due to a heavy snowstorm.

(269) **Asteroid collisions.** *Sky and Telescope*, **11** (*May*, 1952).
Note on an investigation as to possible collisions between asteroids, carried out by Dr. Stefan Piokowski of Krakow. It is concluded that several millions of tons of matter are pulverized annually in the Asteroid Belt.

(270) **Possible lunar meteors.** *Strolling Astronomer*, **6** (*May*, 1952).
Report on recent searches made for lunar meteors and meteor trails carried out by members of the Association of Lunar and Planetary Observers.

ATMOSPHERE

See also abs. no. 297, 299.

(271) **High altitude research at the Applied Physics Laboratory.** L. W. FRASER. *Johns Hopkins Univ., A.P.L., Bumblebee Series, Rept. No.* 153 (*May*, 1951).

(272) **Where does space begin?** H. STRUGHOLD *et al.* *Weltraumfahrt* (3), 69-71 (*July*, 1952). (*In German.*)
Functional concept of boundaries between atmosphere and space. The functions of the atmosphere (oxygen supply, filter against cosmic factors, supply of mechanical support).

BIOLOGY AND MEDICINE

(273) **Method of establishing the biological effects of cosmic radiation at high altitudes.** J. EUGSTER. *Schweiz. Astronaut. Arb.—Bull.*, (1), 6-12 (*Jan.*, 1952). (*In German.*)
Cells of living matter kept at constant temperature were taken to altitudes up to 30,000 m. by balloon. No effects have so far been observed.

(274) **Man in space.** H. HABER. *Weltraumfahrt* (1), 13-16 (*Jan.*, 1952). (*In German.*)
Temperature, cosmic ray factors and absence of gravity are discussed. Space sickness has to be expected.

(275) **Effects of acceleration on the human body.** *Weltraumfahrt* (2), 48-49 (*April*, 1952). (*In German.*)
Typical military manoeuvering accelerations and human tolerance.

(276) **Method to prove the biological effects of cosmic radiation at high altitudes.** J. EUGSTER. *Weltraumfahrt* (2), 42-46 (*April*, 1952). (*In German.*)
Experiments with eggs of arthemia salina and human epidermis. Specimens show effects of cosmic radiation.

CHEMISTRY

(277) **The mechanism of the catalytic decomposition of hydrogen peroxide by silver.** R. L. WENTWORTH. *Massachusetts Institute of Technology Report No.* 32 (1*st May*, 1951).

(278) **The vapor phase reaction between hydrazine and oxygen.** E. J. BOWEN and A. W. BIRLEY. *Trans. Faraday Soc.*, **47**, 580-583 (*June*, 1951).

(279) **The thermal decomposition of nitromethane.** T. L. COTTRELL. *Trans. Faraday Soc.*, **47**, 584 (*June*, 1951).

(280) **Flame speeds in hydrazine vapor and in mixtures of hydrazine and ammonia in oxygen.** R. C. MURRAY and A. R. HALL. *Trans. Faraday Soc.*, **47**, 743-751 (*July*, 1951).

MISCELLANEOUS

(281) **Josef Stemmer, first secretary of the International Astronautical Federation.** *Weltraumfahrt* (1), 11-12 (*Jan.*, 1952). (*In German.*)
Short biography.

(282) **The International Astronautical Federation.** J. STEMMER. *Schweiz. Astronaut. Arb.—Bull.*, (1), 2-4 (*Jan.*, 1952). (*In German.*)

(283) **Karl Schütte now president of GfW.** *Weltraumfahrt* (3), 93 (*July*, 1952). (*In German.*)
Short biography.

(284) **Wernher von Braun.** *Weltraumfahrt* (3), 65-68 (*July*, 1952). (*In German.*)
Biography.

(285) **Kurd Lasswitz and space travel.** E. LASSWITZ. *Weltraumfahrt* (3), 79-80 (*July*, 1952). (*In German.*)
Memories of the author of the novel "Auf zwei Planeten."

PHYSICS

(286) **Tables of contributions to thermodynamic properties due to gas imperfections.** W. B. WHITE. *Rand Corporation Report No. RM-36* (15*th Aug.*, 1950).

(287) **Heat transfer, pressure drop, and burnout studies with and without surface boiling for de-aerated and gassed water at elevated pressures in a forced flow system.** H. BUCHBERG, F. ROMIE, R. LIPKIS and M. GREENFIELD. *Heat Transf. Fluid Mech. Inst.*, 177-191 (*June*, 1951).

(288) **Liquid superheat and boiling heat transfer.** B. R. MEAD, F. E. ROMIE and A. G. GUIBERT. *Heat Transf. Fluid Mech. Inst.*, 209-216 (*June*, 1951).

(289) **Heat transfer and pressure drop data for high heat flux densities to water at sub-critical pressures.** W. M. ROSENOW and J. A. CLARK. *Heat Transf. Fluid Mech. Inst.*, 193-207 (*June*, 1951).

(290) **On the problem of chemical ignition of thermo-nuclear reactions.** E. SÄNGER. *Z. Naturforsch.*, **6a**, 302-304 (*June*, 1951). *In German.*)
Discusses the possibility of attaining extremely high temperatures (up to $2 \times 10^{8\circ}$ K.) by means of converging compression shocks as obtained in detonations.

(291) **Some experiments on the heat transfer from a gas flowing through a convergent-divergent nozzle.** O. A. SAUNDERS and P. H. CALDER. *Heat Transf. Fluid Mech. Inst.*, 91-106 (*June*, 1951).
Gas velocities up to Mach 1.75 and temperature of 865° C. Consistent results with good agreement with formulae for low-speed turbulent flow over a flat plate were obtained.

(292) **Heat flow in composite slabs.** E. MAYER. *J. Amer. Rocket Soc.*, **22**, 150-158 (*May-June*, 1952).
Analytic expressions are obtained for the temperature distribution in a composite wall consisting of an inner refractory medium and an outer metallic medium.

(293) **A similarity law for stressing rapidly heated thin-walled cylinders.** H. S. TSIEN and C. M. CHENG. *J. Amer. Rocket Soc.*, **22**, 144-149, 167 (*May-June*, 1952).
A similarity law is deduced whereby strains for the hot cylinder can be simply deduced from measured strains on the cold cylinder.

PROJECTILES

(294) **Nomogram for artillery rockets.** G. WEIBULL. *Artill. Tidskr.*, **80**, 171-182 (1951). (*In Swedish.*)
Nomograms for powder rockets driven only on the first part of their trajectory.

(295) **The Bowen ribbon-frame cameras.** T. J. OBST and J. A. CLEMENTE. *NAVORD Report No.* 1273 (*15th Jan.*, 1951).

(296) **Celestial guidance for missiles.** J. G. STRONG. *Aero. Dig.*, **64**, 20-25 (*Jan.*, 1952).
Possibilities for the use of the Sun and Stars.

(297) **The first 7 Viking rockets.** H. GARTMANN. *Weltraumfahrt* (2), 50-52 (*April*, 1952). (*In German.*)
Survey of Viking development and a table of the first seven launchings.

(298) **Rockets and A-bomb research.** *Discovery*, **13**, 182-183 (*June*, 1952).
Use of smoke trails for investigating air movement after A-bomb explosion.

(299) **An instrument for high altitude research.** H. GARTMANN. *Weltraumfahrt* (3), 90-91 (*July*, 1952). (*In German.*)
Survey of Aerobee development and comparison with some other large rockets.

RADIO AND ELECTRONICS

(300) **Step multiplier in guided missile computer.** E. A. GOLDBERG, *Electronics*, **24**, 120-124 (*Aug.*, 1951).

(301) **Guided Missile Test Center telemetering system.** J. B. WYNN and S. L. ACKERMAN. *Electronics*, **25**, 106-115 (*May*, 1952).
Sixteen channels are used on a single carrier. Six of these may be used on a time-multiplexing basis to provide up to 172 information channels. Data is stored on magnetic tapes.

ROCKET MOTORS

See also abs. no. 251, 291, 292, 293.

(302) **A theory of unstable combustion in liquid propellant rocket systems.** M. SUMMERFIELD. *Heat Transf. Fluid Mech. Inst.*, 217-230 (*June*, 1951).
Mathematical investigation of the low-frequency vibration known as "chugging." The theory assumes an ignition time lag and considers the effects of liquid inertia in the feed pipes and chamber capacitance.

(303) **Graphical representation of the various parameters used in the study of rocket motors.** M. BARRÈRE. *Rech. Aérodyn.*, (25), 29-38 (*Jan.-Feb.*, 1952). (*In French.*)

(304) **Turbine means for driving the fuel pumps of rockets.** A. CHILTON. *U.S. Pat. No.* 2,585,626 (*12th Feb.*, 1952)
Use of combustion chamber gases for driving turbine.

(305) **Notes on combustion calculations.** V. T. BOEDEWADT and R. ENGEL. *Rech. Aérodyn.*, (26), 19-30 (*March-April*, 1952). (*In French.*)
The various methods are reviewed with special reference to initial conditions. A new method is proposed for rocket propellant performance calculations.

(306) **The Armstrong-Siddeley rocket "Snarler ASSn 1."** *Weltraumfahrt* (2), 47 (*April*, 1952). (*In German.*)
Description of the new propulsion unit.

(307) **Suggestions for the description of the performance of a rocket.** H. GARTMANN. *Weltraumfahrt* (2), 46 (*April*, 1952). (*In German.*)

(308) **Fluctuations in a spray formed by two impinging jets.** M. F. HEIDMANN and J. C. HUMPHREY. *J. Amer. Rocket Soc.*, **22**, 127-131, 167 (*May-June*, 1952).
Experimental study of effect of various injector parameters on frequency and spray pattern.

(309) **Injector spray and hydraulic factors in rocket motor analysis.** K. R. STEHLING. *J. Amer. Rocket Soc.*, **22**, 132-138 (*May-June*, 1952).

Various types of injector compared. Research methods such as use of dyed water and high-speed photography described. Discussion of hydraulic "flip."

(310) **A comparison of adiabatic and isothermal expansion processes in rocket nozzles.** H. S. SEIFERT and D. ALTMAN. *J. Amer. Rocket Soc.*, **22**, 159-162 (*May-June*, 1952).

In the isothermal case jet velocity is limited only by the pressure ratio or energy content of the source supplying the heat. Formulae for the isothermal case are developed.

(311) **The transfer functions of rocket nozzles.** H. S. TSIEN. *J. Amer. Rocket Soc.*, **22**, 139-143, 162 (*May-June*, 1952).

The transfer function is defined as the fractional oscillating mass flow rate divided by the fractional sinusoidal pressure oscillation in the chamber. This is calculated as a function of the frequency of oscillation.

ROCKET PROPELLANTS

See also abs. no. 305.

(312) **High reaction energy substances for jet and rocket propulsion, a review of existing literature.** L. E. SWEARINGEN and A. VEIS. *U.S.A.F. Air Materiel Command Tech. Report* 6633 (*May*, 1951).

REVIEWS

Space Medicine

(Edited by John F. Marbarger. 83 pp., with 18 figs., pub. The University of Illinois Press, Urbana, 1951. 24s. 0d.)

For three dollars spent on this publication you get rather less than 15,000 words, or about an hour's reading, including a certain amount of medical information in the last quarter of the book. The remaining three-quarters deal mainly with rocketry, Martian botany and solar physics. It is not a textbook on space medicine, as one might imagine from its price and exterior get-up, but is a reprint of a symposium held in Chicago on March 3, 1950. This was the second symposium of its kind, the first having been held in the autumn of 1948.

Major-General Harry G. Armstrong, Surgeon-General of the United States Air Force, relates in an introductory chapter, that the School of Aviation Medicine, now at Randolph Field, Texas, was founded in its original form in 1917. A new department of this school, the Department of Space Medicine, was set up about two years ago, and, he says: "For the past two years this laboratory has been devoting its efforts to determining theoretically the effects on the living organism of travel beyond the stratosphere." However, the book contains nothing that could be recognized as the result of laboratory work by such an institution.

A preface of 100 words and a foreword of 300 are each written, we are allowed to know, by a Professor of Physiology; but the five main chapters giving scientific information are by authors whose professional qualifications are not mentioned, though three of them are described as of the Department of Space Medicine.

A book with this title, if intended for medical men with no knowledge about space travel, should begin by telling them how it is likely to be achieved, and what strains will be inflicted on the travellers by engineering requirements.

Wernher von Braun performs this function, but at such length, that his chapter, entitled "Multi-Stage Rockets and Artificial Satellites," takes up nearly a quarter of the book. It includes three points of medical interest. The purpose of rotating a space station is stated and the diameter of a particular model is given, but not its speed of rotation. The estimated duration of a journey from a space station round the Moon and back, 232·13 hours, is stated, but not the duration of an interplanetary voyage. And the various accelerations of a three-step rocket of his own design are given, but not those of any other form of space vehicle.

The first step of von Braun's rocket reaches 9 *g* just before cut-off, and the second step 8 *g*. This is the only piece of definite information in the book about maximum rocket accelerations. Not one of the other authors mentions whether, and if so how, the human frame can stand up to 8 *g*, 9 *g* or any other value of *g*. Nor is there a word from any of them about shielding for the crew of an atomic-powered rocket, which in any case is dismissed by von Braun with the remark that he does not believe it to be "just around the corner."

The next chapter, by Hubertus Strughold, is undoubtedly the most interesting and original in the book. A search through the bibliography reveals that Strughold once collaborated in a textbook on aviation medicine, and indeed his chapter does include one medical paragraph about the oxygen pressure needed by man and the effect of its sudden removal. For the rest, he shows himself an imaginative allround biologist, willing to give of his best in a discussion on the possibilities of life on other planets.

The greater part of his chapter concerns the supposed vegetation on Mars. He points out that most earthly plants, including lichens, contain large air spaces, and that if Martian plants produce oxygen by photosynthesis, they could keep it within such spaces and use it again for respiration, thus solving the problem of lack of oxygen in the atmosphere. This idea had occurred to the reviewer some years ago, together with its corollary, the possibility of animal life stealing the oxygen, which does not seem to have occurred to Strughold but has been thought of independently by Arthur Clarke and introduced into his novel, *The Sands of Mars*.

The unknown artist who drew the diagrams for this chapter is to be congratulated. Particularly good is the one which shows that, on those parts of the Earth possessing the same temperature range as on Mars, only lichens, mosses and shrubs are able to grow.

On one point Strughold is to be criticized, when he states that the giant planets "are past all hope for active life" because their surfaces are too cold: the visible surfaces of Jupiter, Saturn, Uranus and Neptune are only the tops of their atmospheres. If these atmospheres are stirred by turbulence, for which there is visible evidence on the first two, then they must become rapidly warmer with increasing depth, owing to adiabatic compression in the down-currents. A few score miles down, in fact, these atmospheres could be too hot for life, rather than too cold.

Next we have a chapter by Heinz Haber, which is entitled "Astronomy and Space Medicine," and is about astronomy. An explanation of weightlessness, given with more length than clarity, is followed by the short sentence:

"Setting aside the cosmic rays and the meteors," and then the author gets down to solar physics, starting at the middle of the Sun. After many pages we emerge into outer space with a lot of ultra-violet radiation and X-rays whose "existence constitutes a major problem of manned rocket flight at highest altitudes." The problem is not dealt with.

"Orientation in Space," by Colonel P. A. Campbell, was found so excruciating in style, jargon and grammar that this reviewer was hard put to it to search for a few sentences of real interest. If you want to say that gravity is everywhere, why write: "I believe we all agree that gravity is about as permanent and as unavoidable as any part of our environment"—as if there were some doubt about it? We have also to put up with "this phenomena," and then, as if to assure us that he knows his Latin plurals if not the Greek ones, the author twice perpetrates "apparati." There is no such word. The Latin plural is "apparatus," spelt the same way as the singular, but with the "u" pronounced long instead of short. Another howler is: ". . . periods of constant velocity, i.e., in the gravity-free state."

Colonel Campbell lists the three factors in orientation; stripped of the scientific jargon, these are: vision, the inner-ear apparatus, and bodily sensations. Any two of them, he points out, will normally suffice for orientation. Furthermore, air pilots have shown that they can be trained to orientate themselves by vision alone, even when both the inner-ear apparatus and the bodily sensations are giving false information to the brain. So there is some hope.

Finally, Konrad Buettner, writing on "Bioclimatology of Manned Rocket Flight," gets down to some real space medicine without padding. After a practical section on temperature regulation of the cabin, amplified later in an appendix, he poses a problem which, to the best of the reviewer's belief, nobody else has yet thought of—that of ventilation by convection in the weightless state. Normally, the air surrounding our body is carried up by its warmth and consequent lightness, allowing fresh air to take its place. But where neither fresh nor foul air have weight, a motionless human body would soon become enveloped and suffocated, he says, by a cloud of carbon dioxide and water vapour.

We venture to doubt this. Of the millions living in hot climates who indulge in a siesta in the heat of the day, many must have done so in calm, hot air of such temperature as to possess the same specific gravity as that which they breathe out; yet we never hear of anyone perishing of suffocation under such conditions. Perhaps it is because the breath is expelled with some force. In any case, whatever apparatus is used in a spaceship cabin to absorb carbon dioxide and put forth fresh oxygen, it should keep a certain amount of circulation going. But to be on the safe side, the problem should certainly be investigated.

Protection from harmful radiations is also discussed by Buettner. He shows that even if only one-twentieth of the solar X-rays were "hard," lead shielding would be needed, but if this was kept thin to save weight, it would intensify the production of cosmic ray showers in dangerous amount.

Finally he lists, among three medical problems "of immediate concern,"

the suspected effect of increased solar radiation on the eclampsia of pregnancy. But as the space doctor is unlikely to be called to such cases until permanent colonies are established on other planets, the immediacy of this problem is not obvious.

There is no index, but it will hardly be missed. The reviewer's home-made index contains two items: Weightlessness, pp. 23, 53, 66; Acceleration, p. 53.

The inadequacy of the information given in this book is not excused by saying, on the dust-cover, that it has had to be restricted to "declassified material." To mention only one matter, a vast amount of knowledge has been accumulated about the effects of acceleration on the human body in every attitude, all of which has been published and is available to a potential enemy, so why hide it from potential friends?

For those who feel unable to spend three dollars on the first book to be published with this title, preferring perhaps to save up for the first textbook on the subject, there is a cheaper edition of *Space Medicine* in paper covers at two dollars. After spending this, any small change left over could be well invested on a copy of *Weltraumfahrt* (organ of the G.f.W.) for August, 1951, where the problems of weightlessness are discussed informatively and at length, though in German, by seven physiologists. The cost? Ninety pfennigs, equivalent to 1s. 6d.

A. E. S.

Foundations of High Speed Aerodynamics

(Compiled by George F. Carrier. 286 pp. Dover Publications Inc., New York, 1952. $1.75.)

This book contains facsimiles of nineteen fundamental studies of various problems of high-speed aerodynamics, as they were originally reported in the scientific journals of some half-dozen countries, sampling the progress of 80 years of thought.

The subject matter concerns the mathematical theory of compressible fluid flow: and, for the theoretician, it is an intriguing miscellany of oddities and profundities. Here we find Rankine's first essay on the shock wave, developing in 1870 a theory which is now fundamental. Here, too, is Meyer's thesis, describing what we now call the Prandtl-Meyer expansion in supersonic flow; a paper by Ackeret, though not the one for which his name is now so famous; a description by Busemann of his "second order" theory of supersonic flow, written in 1935, and containing incidentally some remarkable allusions to swept-wing supersonic aircraft; Glauert's classic work on compressibility effects at subsonic speeds; Karman and Moore's work on the drag of projectiles.

Of the more recent papers, we find Liepmann's experimental report on boundary layer and shock-wave interaction; and Lighthill's adventurous excursions in the hodograph plane. But if one criticism may be allowed, it is that the other papers presented here as representative of the work of the last decade pale by comparison with the classical studies in whose company they appear. They seem curiously insignificant and narrow in concept; and surely their

inclusion is the compiler's error, for they do not pretend to be fundamental studies. The excuse cannot be pleaded that the last ten years have yielded nothing of note: R. T. Jones' work on slender wing-body combinations, and Crocco's work on the compressible boundary layer, to mention but two examples, will surely long be remembered.

However, it is very easy to criticise the choice, which must largely be a matter of personal opinion. There are enough good things in here to interest the student, though it seems doubtful if some of the papers will tell him very much, as the subject matter is so fundamental as to be almost "elementary" in these enlightened days. On the other hand, the book is of no use as an introduction to the subject as by its very nature it is too discursive and fragmentary in its treatment. So one is forced to the conclusion that, apart from its extensive bibliography, the book has little utilitarian value—except to the reference library where it will add a little historical interest. Fortunately, use is not the only criterion of worth: it has a curio value—at least to your reviewer—and the publishers, for their part, hope that by glimpsing the workings of the masters' minds something may stir the reader to even greater things. Well, I hope so—indeed I do. T. N.

Out of the Sky.

An Introduction to Meteoritics

(By H. H. Nininger. x + 336 pp., with 52 plates. University of Denver Press, 1952. Price $5.00.)

The study of meteorites, the only parts of the extra-terrestrial universe with which we can (at present) experiment and not merely observe, has an importance to many branches of science, notably astronomy, geology and mineralogy. The astronomer in particular is interested in the composition of meteorites as chemical samples of the universe, and in their structure for the clues which are given to the physical conditions prevailing at the time of their formation, and hence to further evidence relevent to the vexed question of the origin of the solar system. The techniques of investigation are, however, not astrophysical but rather mineralogical and metallurgical, and it is to be hoped that the coining of the new term "meteoritics" for the subject (however lacking in euphony) may signify an increased co-operation between astronomers and the laboratory investigators.

The first problems that meteoriticists (!) must tackle are the location and classification of falls, and a statistical analysis of the information so obtained. These problems, particularly those involving selection effects (such as the preferential recovery of iron meteorites) are not always straightforward. The author of *Out of the Sky* has been an assiduous collector of meteorites for many decades; it would be natural, therefore, for this aspect of the subject to occupy the major part of the work, and so it does. The volume is a mine of information on the structure and composition of meteorites, and of copious notes of the circumstances of individual falls. The classification of meteorites is considered at length, and many of the meteorite types and their structures are illustrated

in the numerous photographs, which unfortunately are treated unjustly by a poor-quality paper.

The book is less satisfactory when dealing with the more theoretical aspects of the origin of meteorites, the physics of their formation and their interaction with the atmosphere, etc., all of which are treated in a purely descriptive and very naive fashion. In fact, the text suffers from a tendency common to many introductory volumes from America, to deal with a science in the manner of a natural history only. Too many minute details of observations, many of doubtful scientific value (such as Farmer X's remarks to his wife on the occasion of the meteorite fall at Nether Wallop) are given at the expense of the unifying theoretical concepts and hypotheses that characterize true science. Many readers will find this treatment falls between the Scylla of minutiosity and the Charybdis of triviality. To some extent this fault is inevitable in a young science, but if meteoritics implied no more than is herein contained, the term would indeed be a pretension. But, in fact, there is much of solid substance that has been omitted.

Out of the Sky thus achieves much of value as an encyclopedia of the characteristics of meteorites, individually and collectively, but fails to be a truly satisfying introduction to meteoritics. Let us hope that the embryo science will not have long to wait for the more comprehensive and serious treatment that it deserves. M. W. O.

The Aeroplane Directory

(Pub. by Temple Press, Ltd., E.C.2. 434 pp. 15s.)

The 1952 edition of this directory is, as in former years, a fund of interesting and useful information on British aviation and allied matters.

The B.I.S. will be found listed among the *"Learned Bodies, Professional Societies, and Clubs,"* while the names of A. C. Clarke, A. V. Cleaver, and a number of other members are included in the biographical section. This publication is invaluable as a reference source to anyone concerned with aeronautics. A. V. C.

Rockets, Missiles and Space Travel

(By Willy Ley. 436 pp., 64 figs., 22 plates. Chapman and Hall Ltd., London, 1951. Price 30s.)

This book is an enlarged version of *Rockets and Space Travel* published in 1948, and as the new title implies, much fresh material on missiles has been added. Several chapters have been drastically re-written and a chapter on the White Sands Proving Grounds has been included. The number of photographs and diagrams has also been considerably increased.

The plan of the book has not been changed from that of the earlier edition. It is divided into three main parts. The first part is historical and deals with most concepts of astronomy and ideas of space travel which have arisen during the past 2,000 years. Continuing, it describes the development of rockets from the Chinese fire arrows of the 13th century to the war rockets of the 19th century; it recounts the turbulent history of the German "Society for Space

Travel" (V.f.R.), whose members eventually formed the nucleus of the huge Peenemünde establishment which produced the V.2; finally, it brings history as far as possible up-to-date with a description of post-war American work at White Sands, culminating in the 250-mile climb of a W.A.C.-Corporal launched from a V.2. The second part of the book is concerned with space travel and describes the problems of launching and navigating a space ship, the vessel itself and life within it, and the idea of the orbital rocket which has received so much attention lately. Finally, there are several appendices containing principally much information on rocket aircraft and missiles, also quite a comprehensive bibliography.

The author obviously has a firm grasp of his subject and a very readable style which in no way impairs the accuracy of his book. His long personal association with rocket work (he was a founder-member of the V.f.R.) fits him well for an historian, and his account of the early days of the V.f.R. makes fascinating reading. Very few mistakes are to be found in the text, and these few appear to be slight printing errors which have crept into the mass of data presented in the appendices. They are generally obvious: the cap length of the Nebelwerfer is given as 7·13/16 lb. for instance. These appendices are most useful sources of information. The main use of the bibliography lies in its references to historical and other books on the subject (including fiction). Its list of technical reports and articles must necessarily grow rapidly more incomplete since the output of such is considerable for so young a science, and much of that must remain inaccessible to general readers. A number of Russian books are listed, and the majority of us will be slightly irritated or left with a vague feeling that our legs are being pulled on being soberly told after reading a line of Russian hieroglyphics that "several other articles bearing the same title appeared during the years 1911–14 in the now defunct aviation magazine *More Hieroglyphics*."

This book deserves to be widely read. Its easy, almost conventional style will appeal to the layman, while the rocket technician should read it to fill in the background to his work. There is a deplorable modern tendency for technical education to become more specialized and to leave little time for liberal studies. The engineer will receive little practical help from this book (although the appendices make a useful reference book in themselves), but it is to be hoped that he will read it to learn how his subject grew up, to see it in a truer perspective, and so to clothe with flesh the bare bones of his technological education. D. H.

Jets, Rockets and Guided Missiles

(By David C. Cooke and Martin Caidin. McBride Co., New York, 1951. 192 pp. $2·95.)

The publisher's blurb (there is no Preface) claims that in this book "the history of rockets, jets and guided missiles . . . is unfolded for the first time in readily-understood language." Apart from the word "first," that is a fair statement.

The eleven chapters deal respectively with pre-war powder rockets, early

liquid propellant rockets, history of guided missiles, German, Japanese, Russian, British and American work, post-war developments, history of jet propulsion, how the jet engine operates, modern jet aircraft.

The 71 illustrations include a good selection of current U.S. guided missiles and jet aircraft, and the average reader should find this an interesting volume.

Some, however, may be surprised to learn that since January 9, 1944, "the U.S. has retained the lead in jet aircraft," but the authors are concerned only with military applications and with planes rather than engine design.

Something must have gone wrong when the proofs were corrected. An errata slip has been inserted (an act of duty which does much to mitigate the offence) listing 25 mistakes. These include three transposed captions, but most are simple misprints. There are others.

For British readers this book retails at 22s. 6d. Since the type is large and the illustrations are not on art paper, it must be considered expensive.

G. V. E. T.

CORRESPONDENCE

Design of Rocket Motors

SIR,

I have read, with great interest, Mr. Hurden's paper, *The Design of Rocket Motors*, published in the May *Journal*, and would like to congratulate the author on a very comprehensive statement of the problems which face the rocket designer. There are, however, a few specific observations which I should like to make, as follows:—

1. Fig. 1, showing the comparison between the weights of pressure and pump-fed motors, is the sort of chart to which a designer would refer at a very early stage in his design investigation. At such a time, the thrust requirement would be known (or, at least, assumed) and a comparison of the weights of the different motors would be required for motors *each of the optimum design for the given thrust*. Unless this is done the comparison must become vague and possibly misleading. Under optimum conditions of design it can be shown to within a fairly close approximation that the weight of a rocket motor can be divided into two parts. The first part, which includes the combustion chamber, valves and the pumps, (in the case of the pump-fed arrangement), will vary as the thrust, whereas the second part, comprising the propellant tanks and (in the case of the pressure-fed system) the means for pressurizing them, will vary as the total amount of propellant or the total impulse. Thus we can write:—

$W = K_1T + K_2Tt$ for the pump fed system and

$W = K_3T + K_4Tt$ for the pressure fed system

where W = wt. of motor including tanks

T = thrust

t = duration

and K_1, K_2, K_3 and K_4 are constants.

It will be apparent that $K_1 > K_3$ since K_1 must include the pump weight,

while $K_4 > K_2$ since K_4 must include the heavier pressurized tank weight and the weight of pressurizing system, etc.

The above equations can be rewritten:—

$W = K_1T + K_2I$ and

$W = K_3T + K_4I$ where I is the total impulse. The cross-over point in Fig. 1 will hence occur when $I = \dfrac{(K_1 - K_3)}{(K_4 - K_2)} T$ and will depend on the value of thrust. All else being equal therefore, Fig. 1 is strictly applicable to only one particular value of thrust, and to assume that the cross-over point will occur at the same value of total impulse for other thrust values is quite erroneous.

A more general and useful method of showing the relative merits of pump and pressure feeding would be to plot *specific weight* against *duration*. Transposing the two equations above we have:—

$\dfrac{W}{T} = S_w$ (specific weight) $= K_1 + K_2t$ for pump feeding

$\dfrac{W}{T} = S_w = K_3 + K_4t$ for pressure feeding.

The cross-over point then occurs when $t = \dfrac{(K_1 - K_3)}{(K_4 - K_2)}$, which is independent of thrust and is affected only by the design parameters pertaining to the two competitive systems.

2. The choice of optimum chamber pressure is perhaps not quite as simple as is suggested. It should be emphasized that Fig. 2 is only a typical curve for a given application. As the duration of the motor increases, the reduction in total weight resulting from the small but positive improvement in consumption which would be obtained by using a higher chamber pressure will more than balance the attendant increase in dry weight. Consequently, for long duration motors, such as for long-range missiles and aircraft, the optimum chamber pressure will certainly tend to be higher than that indicated on Fig. 2.

Another factor which influences one's choice (quite apart from the efficiency increase resulting from higher expansion ratio) is that, in general, combustion processes take place faster and more smoothly at higher pressures. It might therefore be worthwhile sacrificing an increase in chamber and pump weight in order to run at a higher pressure, when steadier and more efficient combustion is likely to be obtained.

Both the above arguments are especially pertinent when choosing the maximum pressure for a rocket motor which is required to run over a range of thrusts. The minimum thrust at which it is possible to run and the consumption at such a condition will depend, partly at any rate, on the chamber pressure, and a high maximum pressure is dictated if a wide working range is to be achieved.

3. There is also considerably more to the choice of chamber wall thickness and coolant velocity than is indicated in the paper, as I feel sure Mr. Hurden would be one of the first to admit. The optimum choice of these parameters as determined by calculation may not be obtainable in practice because of pure

engineering considerations. The coolant velocity may well be limited by the maximum permissible drop in pressure through the jacket. The temperature rise of the coolant (especially in the case of certain propellants) might be critical and influence the overall design. Finally, the outer wall temperature might be decided by the particular coolant used and the desire to suppress or encourage nuclear boiling, as the case may be.

With the present state of the art, the sort of heat transfer calculation, which Mr. Hurden describes, can serve only as a guide to show general trends and influences. Until we have more fundamental data on the physical characteristics of both combustion gases and rocket propellants, and a more intimate knowledge of the whole process of heat transfer, it will only be possible to make intelligent guesses (often influenced more by past experience than by pure calculation) and look to practical tests for the final answer.

W. N. NEAT.

Kenton,

Harrow, Middlesex.

Power Generation in Satellite Vehicles

SIR,

While in general agreement with the substance of the paper by Mr. Cross (*J.B.I.S.*, **11**, (3), May, 1952), it does contain some mis-statements which I should like to correct, as follows:—

(*a*) Mr. Ross did *not* state that the "power requirement of the Station would be 1,000 kW."; he said merely that "1,000 kW. would be available," and by that, meant for temporary overload.

(*b*) The boiler area "assigned" by Mr. Cross is given by him without any authority or justification, and is incorrect. He has overlooked the necessity of providing for part of the boiler to be capable of being by-passed for overhaul.

(*c*) The relative proportion of condenser and waste heat radiation areas assumed by Mr. Cross is not correct, nor also is the assumption made by him about the condition of the degraded power intake in this particular instance.

(*d*) The "inlet temperatures" which Mr. Cross regards as a maxima make no provision for the improvement of materials and blading technique during the hundred years or so which will probably elapse before the scheme is likely to be brought into operation. In fact, the limiting temperatures quoted are already out of date!

(*e*) Mr. Cross has ignored the fact that Mr. Ross mentioned the possible use of mercury or mercury-water cycles, but was not rash enough to presume to dictate what the working fluid must be.

(*f*) Mr. Cross calculates the mirror cross section areas between 2,300 and 3,250 sq. metres, according to the system used. The area given by Mr. Ross was just under 3,000 sq. metres!

Our "round figures" were given in a generalized schematic and were not intended to be taken quite so literally as Mr. Cross has done.

(*g*) Mr. Cross states categorically (in the paragraph immediately following Table 3) that "under no circumstances, etc." but contradicts himself and apparently relents in a slightly patronizing concluding paragraph.

I think there is little likelihood that construction of a space station of the sort envisaged would be undertaken until all the operating requirements had been very carefully considered by competent people in the light of the information then obtaining.

There are many other minutiæ of design which Mr. Cross might care to examine, no less important at the proper time, but equally premature at this stage for the reasons given.

R. A. SMITH.

High Wycombe, Bucks.

Interplanetary Dictionary

SIR,

I have for some time been working on a dictionary of words and terms used in "future science," science fiction, the problems of interplanetary communication and travel, etc. I hope to have the volume completed by the end of this year.

Being desirous of making as complete a coverage as possible, I am addressing myself to as many of the writers in the field as I can reach, either personally or through periodicals. I am especially eager that such persons will inform me of words that they have introduced into the vocabulary of the field——word, meaning, place and date of first published use.

I shall be greatly obliged if any of your members who have employed new words send me a note thereof.

The dictionary of new science terms is to be historical, and give author, date, and story (and/or magazine) of first use of the words.

29 West 46 Street,
New York 36, N.Y., U.S.A.

JOSEPH SHIPLEY.

What we know about the Moon

SIR,

I regret that the reference in my lecture (*J.B.I.S.*, (**11**), 26) to the great 300-in. lunar map by H. P. Wilkins is not clear.

It is, of course, perfectly correct that Wilkins' original map was published in the year stated, but I should have emphasised that a new and completely revised edition appeared in 1946, while yet a third edition, again revised not only from personal observations made by Mr. Wilkins, but also from a study of the finest photographs available, has only just been published.

Virtually no inaccuracies can remain in this last edition, which contains charts of special areas and of limb regions not previously mapped at all, and the whole is unlikely to be superseded until the circumlunar rocket becomes an accomplished fact.

I am sorry for my careless wording, which may have created a false impression.

East Grinstead, Sussex.

P. A. MOORE.

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(*a*) "The German A4 Rocket" (*photo British Interplanetary Society*).
(*b*) "View of the Earth at 60 miles altitude" (*photo U.S. Navy*).
(*c*) "Building a Space Station" (drawing by R. A. Smith from *The Exploration of Space*, Temple Press, Ltd.).
(*d*) "The Lunar Landscape" (*photo Lick Observatory*).
(*e*) "The Rocket in a Lunar Crater" (*Scene from Destination Moon*).
(*f*) "Imaginary view of Saturn fromits Nearest Satellite" (from a painting by Chesley Bonestell in *The Conquest of Space*, Sidgwick & Jackson, Ltd.).

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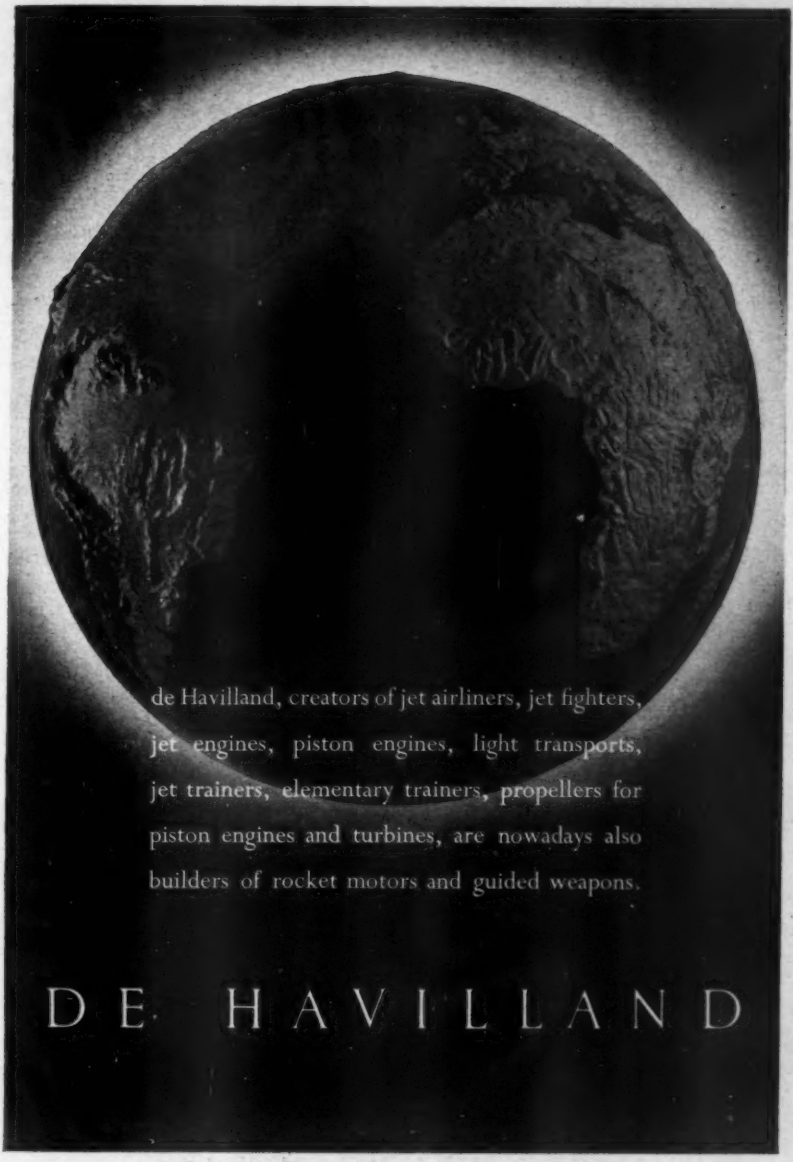
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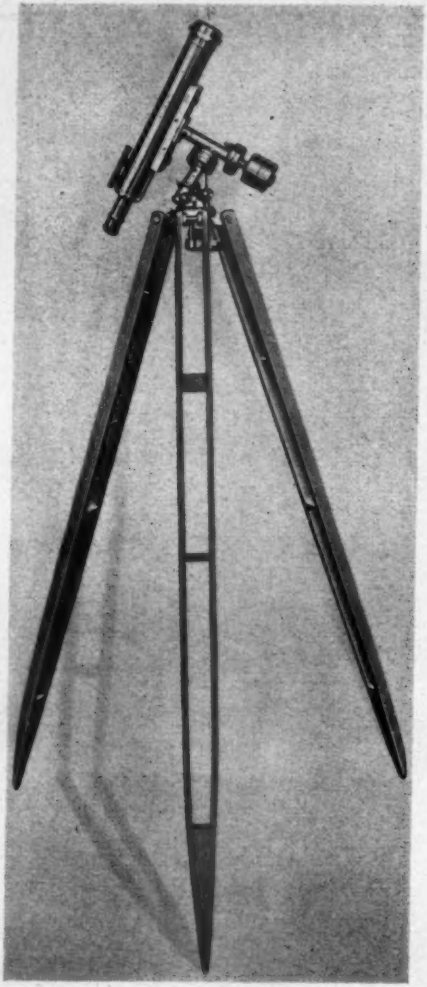

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